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REPORT OF SERIES OF SINGLE-STAGE THORACOPLASTIES

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INTRODUCTION

IN THIS paper it is proposed that single-stage thoracoplasty is the operation of choice for many patients.

Originally it was intended to compare the results of single-stage and multiple-stage thoracoplasties. This comparison, however, was later considered impractical because indications for thoracoplasty five or six years ago were different from the ones that exist today and, since this series began five years ago, our own multiple-stage procedures could not be used as controls.

This series was begun cautiously because all generally accepted standards indicated that a single-stage procedure was hazardous. These standards developed out of the many disasters that occurred in the earlier period when thoracoplasty was an extensive, single-stage operation with the removal of many ribs. The pendulum swung from this extreme to the opposite, a patient having to undergo several major operations in which one, two, or three ribs were removed each time. We believed that with the improvement in anesthesia, surgical technique, and methods for the control of shock, more extensive resections could be undertaken.

The early cases consisted of patients with unstable minimal disease in whom we were unable to establish artificial pneumothorax. After periods of observation varying from four to eight months, it was decided to produce a selective collapse by thoracoplasty, which would approximate that resulting from an ideal selective pneumothorax.

Since the results with these early small thoracoplasties done in one stage were encouraging, it was decided to increase the number of ribs removed at one operation in selected cases with more extensive disease.

If this could be done safely there would be certain evident advantages. Instead of two or more operations, one would suffice. The interference with

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collapse of the apex, due to resistance created by organizing tissues or early rib reformation often encountered at a second stage, would be avoided. In many cases this would result in adequate collapse being obtained, by removal of fewer ribs.

As our experience increased, the complication most frequently considered a definite contraindication to this type of procedure, namely parodoxical movement of the chest wall, failed to appear clinically to any significant degree. We found, in addition, that postoperative shock was considerably less than that which usually followed the second stage of a standard thoracoplasty.

In this series 55 per cent were cases in which no previous collapse therapy had been attempted.

Since these patients were carefully selected, they all had the prime requisite for successful surgery—good general condition.

Age is not particularly important, the patients in this group ranging from 16 to 65. The age distribution as shown by Table I is approximately the same as that for any comparable group.

TABLE I. AGE GROUPS

UNDER 20 YEARS	20 TO 30 YEARS	30 TO 40 YEARS	40 TO 50 YEARS	50 TO 60 YEARS
				(57)
7	32	21	9	3(61)
(16)				(63)

It is naturally preferable to deal with unilateral disease but, as our figures show, this type constituted only 40 per cent of the series. The location of the diseased area to be collapsed is important and should be confined to the upper pulmonary area. There is no difference of statistical significance between right and left lung. The patient should be kept under observation for a period of at least three and preferably six months and in bilateral disease correspondingly longer. Contralateral disease must be under control or at least stabilized. Before the advent of streptomycin, artificial pneumothorax was used when it could be successfully initiated, otherwise a moderately prolonged period of bed rest. However, streptomycin, which we have used extensively since 1947, and more recently PAS have greatly aided in the preparation of a patient for surgery.

TABLE II. DISEASE.

Unilateral	25	Bilateral	47
Operative side		minimal to moderately advanced	
Cavity	28 cases	Size	2 to 5 cm.

Streptomycin is not given to all surgical patients routinely. Its use is indicated in acute exudative lesions, bronchial disease, and where a moderately large cavity is to be collapsed, with the possibility of spread resulting from aspiration of infectious material. In the first two it is given four to six weeks preoperatively, in the latter one week preoperatively, and in all instances continued for at least one month postoperatively.

In cases where the disease extends into the lower half of the lung, we frequently use pneumoperitoneum in addition to autibiotic therapy. When two

TABLE III. PROCEDURE

	Left side		Right side	
Ribs per stage	4	5	6	7
Number of cases	26	36	6	4

methods of therapy are used at the same time it is difficult to assess accurately their respective value. We do believe, however, that pneumoperitoneum is of some benefit in stabilizing mid-lung or lower lung disease.

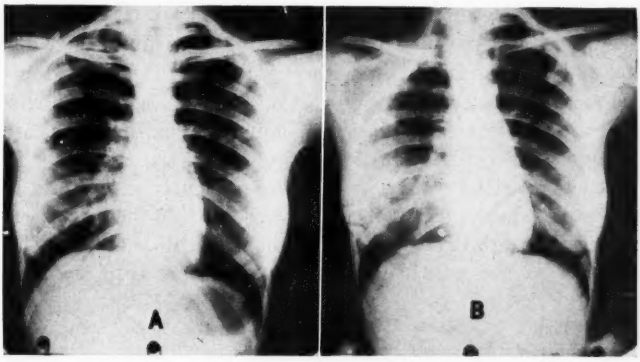

Fig. 1.—Four-rib thoracoplasty.

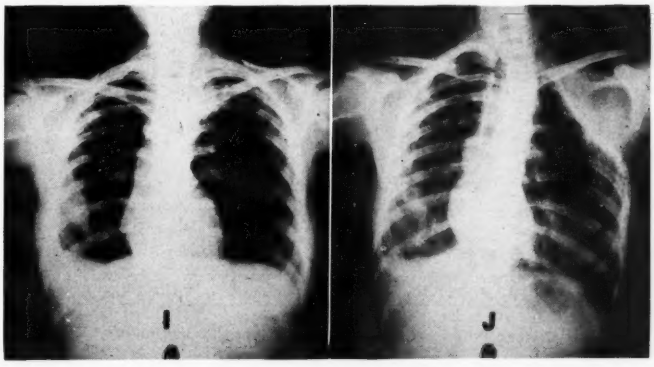

Fig. 2.—Five-rib thoracoplasty.

Investigation is begun with admission to hospital and a tentative opinion is given at that time as to the possibility of surgery for each patient. If it is considered a probability, any intervening treatment is undertaken with this in mind. Routine blood work, complete radiologic study including planograms, and bronchoscopy are done. All this work is repeated as indicated during the period of observation. We do not use the vital capacity test routinely nor have we the facilities for bronchospirometric estimation.

Surgeons who are on the resident staff of a sanatorium and who see patients day after day over a period of months or years, become quite adept in the clini-

cal evaluation of the individual patient. During the period of personal observation, if a patient at any time shows enough signs of dyspnea to indicate the desirability of a vital capacity test, we consider that, in itself, a contraindication to the single-stage operation.

The operative procedure is done under endotracheal cyclopropane anesthesia, supplemented by small amounts of ether.

The incision parallels the medial border of the scapula, and extends from the base of the neck to the anterior axillary line. The muscles are sectioned and the serratus fibers severed from the second rib. The first rib is removed entirely up to, and often including, the costal cartilage. Depending on the extent of the disease, all or moderately large portions of the second and third ribs are resected. Portions of the remaining ribs, four, five, six, or seven, are removed in such a way as to provide gradual tapering of the thoracic cage. The transverse processes of all ribs involved are resected routinely except that of the first. The incision is closed in layers with the scapula outside the ribs when the number removed is not more than five. When the sixth rib is taken out the position of the scapula is ignored and it often falls of its own accord behind the ribs.

TABLE IV. SPUTUM CONVERSION

TIME	3 MONTHS	4 MONTHS	5 MONTHS	6 MONTHS	6 TO 12 MONTHS
	25	6	5	4	10
Preoperative sputum					
Positive		58			
Negative		14			
Conversion		50			
Persistent positive		8			
Source					
Operative side		5			
Bronchial disease		4			
Patent cavity		1			
Opposite side		3			
Persisting preoperative					

TABLE V. POSTOPERATIVE HOSPITALIZATION.

6 MONTHS	6 TO 12 MONTHS	12 TO 18 MONTHS	18 MONTHS	IN SANATORIUM
7	35 (Av. 9 mo.)	18 (Av. 15 mo.)	7	4
	Discharge 59%		9 months postoperatively	

TABLE VI.

	WORKING	WELL	MAXIMUM BENEFIT	IN SANATORIUM
3 to 5 years (13)	11	1 (retired man, 65 years old)	1 (asthmatic)	
2 years (35)	33	1 (retired man, 65 years old)		1 (disease, opposite lung)
1 year (24)	20			3 (1 bronchial, 1 bone, 1 revision)
	Recovery		67 or 94%	

All patients receive intravenous saline during the operation but routine transfusion of whole blood is given only when six or seven ribs are to be removed. This is due to our comparatively isolated location and our limited local supply of blood donors.

Postoperatively, dressings are applied tightly with adhesive. Sedatives are used as required. All patients spend a large part of the first forty-eight hours in an oxygen tent and appear quite comfortable within twelve hours.

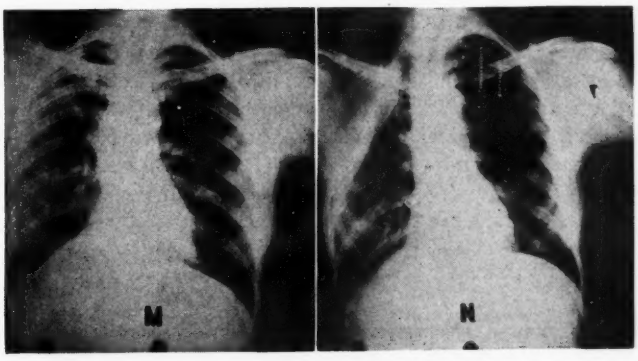

Fig. 3.—Six-rib thoracoplasty.

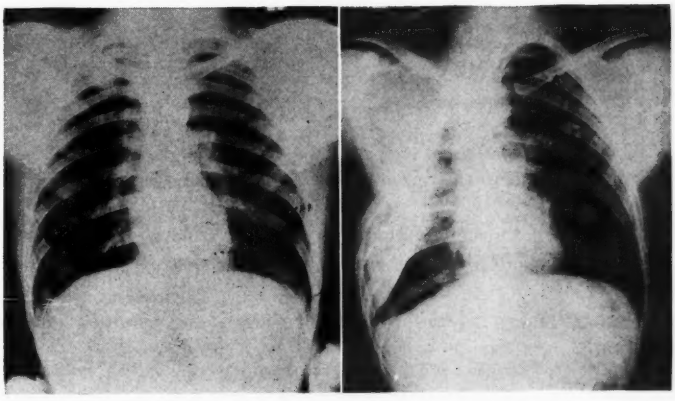

Fig. 4.—Seven-rib thoracoplasty.

In this series postoperative shock has been negligible and, as the operative technique is standard, we feel that some of the credit must go to our staff anesthetist.* Anesthesia is induced quickly with no distraction for the patient and continued at a light surgical level. The patient is usually awake within a few minutes following closure.

Other than the dressings applied at operation, which are taken off ten days postoperatively when the sutures are removed, we use no padding, harness, or

*Dr. Gordon Richardson, Muskoka Hospital, Gravenhurst, Ontario.

other device to compress the collapsed area. The patient is constantly reminded to keep the head slanted to the operative side and to begin movement of the arm as soon as it can comfortably be done, which is usually in a few days.

The results of this series we believe compare favorably with those obtained by multiple-stage procedures.

Table IV shows sputum conversion occurred in 25 cases within 3 months, 40 cases within 6 months, and 50 cases within 12 months. Of the remaining 8 cases, 4 became sputum negative on a second course of streptomycin therapy, and 1 required a revision with more extensive resection.

In considering postoperative hospitalization, it must be remembered that we are dealing with tuberculosis which is a chronic constitutional disease. Consequently the accompanying table of postoperative hospitalization showing the length of time a patient remains in residence after operation, is not of paramount significance in judging the success of the procedure. As it is, instead of speeding up discharge we usually have to use all our powers of persuasion to keep the patients in residence for a period which, in our opinion, is long enough to ensure continuance of recovery.

SUMMARY

We have presented a series of 72 cases of one-stage thoracoplasty with a minimum follow-up period of sixteen months. We would like to submit that this procedure is justified in a certain number of cases and find that with present extended and intensive antituberculosis campaigns, an ever-increasing number of cases fall into this select group. We have completed 21 one-stage procedures since this series. Of these 12 were six-rib and two seven-rib operations. We are very satisfied with the results.

CONCLUSIONS

1. Complete thoracoplasty in one stage is a safe procedure in properly selected cases.

2. The one-stage thoracoplasty often permits adequate collapse to be obtained by the removal of fewer ribs than would be necessary in multiple-stage operations.

3. One operation is preferable to two or three if the results are comparable.

DISCUSSION

DR. JOHN ALEXANDER, Ann Arbor.—Dr. Laird's and Dr. Lindenfield's proposal is interesting and challenging and their results are very good. As part of a critical analysis of their proposal, I am impressed by (1) the relatively inextensive lesions illustrated in a number of the preoperative roentgenograms shown in the lantern slides and (2) Dr. Laird's statement that a considerable percentage of the patients had had no previous collapse therapy; several temporary phrenic paralysis operations with or without a phrenic belt or pneumoperitoneum, or pneumothorax might have been expected to bring about a recovery of at least some of these patients.

I doubt if the demonstrated safety of a one-stage thoracoplasty for relatively inextensive lesions would be duplicated in cases in which the lesions are as extensive and severe as those for which thoracoplasty is so frequently used in many clinics. In the latter group, the cavities are often large, the sputum amount great, and the patients are frequently debilitated by

prolonged tuberculosis. In such cases a one-stage thoracoplasty of six or seven ribs would, I believe, expose the patient to the real dangers of a sudden, great collapse of the extensive tuberculous lesions and to the exaggerated paradoxical respiratory movements that notoriously are likely to occur when even as few as four or five ribs have been widely resected in patients who have many pulmonary secretions to cough up and who may be dyspneic. When there is such paradoxical respirations, sputum is difficult to raise adequately and, under this circumstance, a spread of the tuberculosis in either or both lungs, or atelectasis, often occurs.

When the extensive one-stage Brauer-Friedrich thoracoplasty was used 43 years ago, the mortality was so high that it was soon abandoned. The pendulum then swung far in the opposite direction when Wilms and Sauerbruch resected only narrow paravertebral segments of approximately eight ribs; although this operation was usually performed in one stage, it was much safer than the Brauer-Friedrich operation, presumably because of the total length of the resected ribs was so much less. As the percentage of complete healing of the tuberculosis after the Wilms-Sauerbruch thoracoplasty was disappointingly low, the Brauer-Friedrich type of operation, performed in multiple stages, was finally adopted as being both effective and safe.

I believe that if an extensive one-stage thoracoplasty for extensive far-advanced tuberculosis should be used, the mortality rate would be high, and that the operation would then be rejected.

DR. FRANCIS M. WOODS, Brookline, Mass.—As Dr. O'Brien reminded us in his address, multiple-stage thoracoplasty when properly done is one of deserved reputation and a mainstay in surgical treatment of pulmonary tuberculosis. Physical setback, psychic trauma, and cost attending multiple stages have, nevertheless, been a source of disappointment. We would advise great caution in increasing the extent of single-stage operations unless some principle is used to overcome paradoxical movement of the decostalized chest wall. We have devised a two-stage procedure which applies this principle, and has been used since December, 1948, in 76 cases of cavitary disease, including many with extensive or bilateral cavitation, or both. Twenty patients were 50 years of age or older and, of these, 5 were 60 or over.

(Slide.) At the first stage the periosteum is stripped from all the ribs that would be removed in the usual multiple stages. We have stripped a mamixmum of nine ribs at one time and this was well tolerated.

(Slide.) The space between the ribs on the outside and the intercostal bundles and periosteal beds on the inside is filled with Lucite balls, thus immobilizing the chest wall. In addition, a good layer of tissue with abundant blood supply is interposed between the lung and plombage. The incision is closed.

After four weeks there is adequate fibrosis and rib regeneration in the chest wall to prevent paradox. The second stage is done, removing the Lucite balls and the deperiostealized ribs, including the transverse processes and the first rib.

The sputum has been converted in 16 out of 20 patients, on whom operation was completed more than six months previously. There have been no infections. The danger of late infection or erosion is eliminated by the second stage. The collapse obtained at a single sitting is better. Dr. Overholt and Dr. Kenny of our group are attempting to perfect a procedure which will do away with the second stage by fixing the deperiostealized ribs in an inverted position to stabilize the chest wall.

DR. F. B. BERRY, New York.—I have three slides which I wish to show merely from an historical standpoint, because when I first became a member of this Association and before, many at that period were doing thoracoplasty in a single stage and took out nine, ten, or eleven ribs at one time; roughly, as I recall, the results were looked upon as about in three equal parts—33 per cent died, 33 per cent had pretty good results, and 33 per cent went along with their disease uninfluenced or made worse.

These three slides show a thoracoplasty as it was done at that time and one of this patient taken a month ago. The operation was done when she was 14 years old. It is not the type of thoracoplasty we do today. She was one of the 33 per cent good results and she has

earned her living ever since. She has no deformity and is now going along happily, and I thought that particularly some of the younger members, who were perhaps not even thinking of medical school when this patient was operated upon, might like to see them.

(Slide.) This is the original condition of this girl, with an extensive infiltrating lesion throughout the right side for which she was given pneumothorax.

(Slide.) Then she had the pneumothorax with a long stringlike adhesion. This was before the days of internal pneumonolysis, so no attempt was made to sever that. She also developed fluid, and Dr. J. A. Miller and Dr. A. V. S. Lambert believed that the next step should be thoracoplasty, and certainly from the standpoint of function and longevity they were right.

DR. CHARLES P. BAILEY, Jenkintown, Pa.—I did not intend to discuss this paper but feel that in justification to Dr. Laird and Dr. Lindenfield we must report that we, too, were rash enough to do a few large thoracoplasties in one stage. We have operated upon 15 or 20 patients recently, doing six or eight ribs at a time. We took off the transverse processes and the upper three or four cartilages. We were impressed by the fact that these patients did not have very much surgical shock, nor great paradoxical breathing. It does seem that things are quite different from a few years ago before we had the antibiotics, when resection of only three or four ribs sometimes gave us many anxious hours. We believe that probably the greatest factor in this changed situation is the better management of secretions, and perhaps pretty good selection of cases. We do not do any borderline cases by the one-stage thoracoplasty.

We have found that if we attended to secretions the patients did not have much trouble with paradoxical breathing. If there was any evidence of excessive bronchial secretions, we bronchoscoped them immediately. And if that seemed to be required repeatedly, we did not hesitate to perform a tracheotomy, and did so in four cases. There was no mortality in this series, and in each instance the collapse was perhaps somewhat superior to that obtained in the usual staged procedures.

DR. LAIRD (closing).—Dr. O'Brien warned me that the roof would fall on us; fortunately we are still here. I quite agree with Dr. Alexander, naturally, that these patients are not the extensive and sick patients that are possibly most suitable for thoracoplasty. This is a select group; many of them have had pneumothorax attempted; many are primary thoracoplasties. I think the swing has been toward more frequent thoracoplasties in recent years of a primary nature—that is, for localized lesions, localized apical lesions, in an otherwise well-controlled individual. I believe that in that type of patient, this operation of one-stage thoracoplasty is safe; we have had no mortality in this group. It accelerates the patient's recovery and I think, keeping in mind these factors and the selection of cases, that it is a safe procedure.

FURTHER EXPERIENCES WITH SEGMENTAL RESECTION IN TUBERCULOSIS

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INTRODUCTION

SEGMENTAL resection of the lung is comparatively new in the surgical treatment of tuberculosis. Its objective is to remove not only the diseased components but to preserve the maximum amount of normal lung as well. Though the procedure was done with some hesitancy at first,[1, 2] nevertheless we wish to present our experiences with the first seventy-five consecutive cases done in the last two and one-half years. We are anxious to draw no conclusions at this time because the number of cases is too small and the follow-up period is too short for definitive evaluation. Suffice it to say that the results have been such that we are encouraged to continue its use in carefully selected cases.

GENERAL CONSIDERATIONS

Resistance, both systemic and local tissue immunity, is just as important to the success of segmental resection as in all other forms of therapy in tuberculosis. Resistance, we all know, often compensates for the limitations of surgical therapy, but a major surgical operation rarely alters the course of a tuberculous patient who has little or no resistance. Proper timing of the operative procedure in tuberculosis has been repeatedly emphasized by John Alexander and other early workers in this field. This was another way of warning the surgeon not to operate upon a patient who lacked resistance, and our best results in segmental resection have been in patients who had this important factor.

Resistance is a difficult entity to define, but its existence usually is based upon the composite picture. The *age, race,* and *family history* formulate the patient's background; the *present illness* reveals the degree and duration of *toxicity* up to the time of surgical consideration. The changes in the *physical findings* (observation, palpation, percussion, auscultation), the *vital signs* (temperature, pulse, and respirations), *laboratory studies* (sedimentation rate, red blood count, hemoglobin, etc.), *sputum changes* (character, amount, bacterial content), the *x-ray evidence* (calcification, elevation of interlobar fissures and hilum, mediastinal shift, intercostal narrowing, scoliosis, elevation of diaphragm, resolution, and localization), and finally the very important but intangible factor, *general condition* (appearance, appetite, weight, etc.), when all added together, accurately evaluated and properly weighed leads one to the conclusion that the patient either does or does not have resistance. *To the patient with resistance, surgery is a great adjunct.*

Work done at Triboro Hospital, St. Albans Naval Hospital, Halloran Veterans Administration Hospital and Bellevue Hospital.

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The main offending focus only is removed by segmental resection. This is true of all resection therapy, but it implies that the residual foci are thought to be well arrested. Upon the accuracy with which these residual foci are evaluated depends our ratio of success to failures.

The residual focus is one of three kinds: (1) active, (2) indolent (smoldering), and (3) arrested. The active foci are easily recognized by the changes seen in the serial x-rays. Active foci should not be left behind in resection procedures except in bilateral problems. In a similar way, the arrested foci are recognized by their lack of change as seen in the serial x-rays. Such foci may be left behind with impunity. The x-ray changes in an indolent focus, however, are so slight it is extremely difficult to distinguish them from the arrested one. For this reason *all* residual lesions are treated as indolent foci, and the patient is given six months bed rest as part of the postoperative management.

Cavitary tuberculosis in man is confined, in the majority of cases, to three segments of the lung; namely, the apical and posterior segments of the upper lobe, and the superior segment of the lower lobe (Jackson). We cannot explain this observation but it must have been known to the early workers because the Sauerbruck thoracoplasty removed only short segments of ribs posteriorly and was designed to collapse mainly the diseased components along the vertebral gutter. Such collapse had little influence upon the segments or lobes in the anterior half of the chest. Though this operation was frequently a bacteriologic failure, by preserving the anterior segments it was usually a physiologic success. These facts, and a thrifty desire to preserve lung function, motivated our interest in the segmental removal of tuberculosis.

Medlar[3, 4] fifteen years ago showed experimentally that the location of cavitary tuberculosis in rabbits could be influenced by changes in their living position. Recently, he charted the location of minimal lesions, of the reinfection type, in ninety-six patients who died sudden and unexpected deaths. The great majority of the lesions were in the apical and posterior segments of the upper lobe and the superior segment of the lower lobe. He agrees with Brock[5] that gravity may be mainly responsible, though he expresses interest in the theories of Dock.[6]

The possible transection of tuberculous disease during the segmental separation was a great hurdle to the therapeutic concept of this operation. It was reasoned that during the segmental separation the larger foci could be seen or felt, but the smaller ones, and especially those of microscopic dimensions, might be violated unknowingly. We are confronted with this same problem in the patient upon whom a lobectomy is planned, but at operation is found to have an incomplete interlobar fissure. In such cases the surgeon has the choice of a pneumonectomy or violation of an area which might be diseased. The introduction of streptomycin gave us the courage to cross this diseased barrier during a lobectomy which, from a technical viewpoint, is identical with the technique of segmental resection. It was reasoned that if the lesions near the incomplete fissure were firmly and securely healed no complication would occur, but if indolent or active lesions were present possible exacerbations would be controlled

by the streptomycin. Though this theory may have been unproved at that time, additional experience seems to support it. Division of such a fissure without mishap was one of the advances which made segmental resection in tuberculosis a logical therapeutic procedure instead of a surgical adventure.

Excessive distention of the lung or its components seems to have an undesirable influence upon the activity of the residual foci, especially active or indolent foci. The speed and degree of this distention must also be considered. *Sudden* and marked distention may be avoided in five ways: (1) by a preliminary thoracoplasty; (2) by the "pleural tent" operation as developed by Miscall and Klopstock;[7] (3) by an immediate small thoracoplasty done in conjunction with the resection; (4) by paralysis of the diaphragm; or (5) pneumoperitoneum. However, in the cases selected for segmental resection, sudden and marked overdistention is of much less significance because the healthy segments already have compensated gradually for the slowly contracting diseased segments. In this way the degree of overdistention is neither great nor sudden. Furthermore, small foci which may have been present in the adjacent compensatory segments have stood the test of this overdistention for some time prior to operation. The additional demand immediately after the operation is too small to be of any significance. Though there is considerable clinical evidence that overdistention of a lung or lobe is undesirable in a patient with active or indolent tuberculosis, a good explanation for this observation is still lacking.

TECHNIQUE

The technique of the operation is a meticulous one. In our experience the morbiditiy is in reverse proportion to the speed and care exercised by the surgeon at the time of segmental separation. Though great postoperative vigilance is necessary to assure complete reexpansion, the complications after segmental resection are not only no greater but actually fewer than those following lobectomy.

The actual technique we have used is based upon the contributions of Churchill,[8] Blades,[9] Clagett[10] and Overholt.[11] Churchill and Belsey directed our attention to the fact that the bronchopulmonary segment is the surgical unit of the lung. Blades, aware of the work of Nelson and others, realized that Churchill was actually removing an embryologic lobe (lingula) and was first to report a "partial lobectomy" of the lower lobe. He began at the periphery and worked toward the hilum. Clagget by his "traction-dissection" technique began at the hilum, removed part of the lobe, and then infolded the "raw area" by approximation of the pleural surfaces. Overholt realized that the lung could not "breathe" if the raw area was infolded so he left it open. In this way the segment assumed the natural contour of the thoracic cage. A last refinement in the technique was "pleuralization" of the raw area by a free graft taken from the parietal pleura. Though we continue to "pleuralize" in this way, both Samson[12] and Crafoord[13] have used, rather ingeniously, the visceral pleura from the resected segments.

Churchill, Lindskog, and others have pointed out that bronchiectasis is a segmental disease and respects the intersegmental plane. Lung abscess and tuber-

culosis, however, have little regard for these indefinable borderlines, and often at operation the residual evidence of the previous inflammatory reaction can be recognized in the form of "fibrous scarring" as the intersegmental plane is developed. When this reaction is severe and progress along the normal anatomic border too closely approaches the active disease, an adjacent subsegmental bronchus may be palpated, isolated, divided, and the subsegment removed with the total specimen.

The vascular pattern as pointed out by Boyden and Scannel is characterized by its inconsistency, but the bronchial tree is more reliable. Therefore, the proper bronchus should be identified and divided first. The bronchus can be identified first in both superior segments of the lower lobes and the posterior and apical segments of the right upper lobe, but on the left the apical-posterior bronchus is concealed usually by one or two arteries. No arteries concealing the apical-posterior bronchus, however, should be ligated until *all* branches to the left upper lobe have been identified. The origin of the artery to the left anterior segment has come off the parent artery to the apical segment on occasions, and in two instances it has come off just proximal to the lingular artery. The latter, on the other hand, may originate as one or two vessels, or may come off of the anterior segmental artery in front of the bronchus. These experiences and the teachings of Boyden and Scannel have made us very cautious about ligation of any vessel on the left until all are visualized. Traction upon the distal bronchus soon discloses the associated artery which is isolated, ligated, and also divided. Gentle traction then on these two structures permits the surgeon to begin the segmental resection.

The veins, however, deserve separate consideration. They lie in the intersegmental plane and receive tributaries from the segment to be removed as well as the segment to be left behind. The small tributaries from the segment being removed are often torn across at their junction with the intersegmental vein before they are actually identified. Others are large enough to be ligated and divided, but it is a good general rule to delay the division of any vein until absolutely necessary. In some cases the previous inflammatory reaction has so altered the anatomy that it is extremely difficult to preserve the intersegmental vein. However, other collateral channels are available for venous return if the intersegmental vein is damaged or ligated. Usually, the intersegmental vein can be preserved.

COMPLICATIONS

The number of complications have decreased as our experience increased. The last forty-one consecutive cases have been done without a major complication or death. We previously made the statement that the morbidity in segmental resection was greater than after lobectomy. Our experience now with more than 250 segmental resections for all types of pulmonary disease allows us to believe that not only the morbidity but the mortality rate (2.4 per cent) is no greater than after lobectomy.

MINOR COMPLICATIONS

The absence of operative spreads was a surprise finding. The two spreads which occurred later were associated with the development of a bronchopleural fistula. Local exacerbations in the intersegmental plane were not detectable, if present.

One small superficial wound infection had been incised unsuccessfully on two occasions. The patient's sputum was repeatedly negative on culture.

There were two failures of the lung completely to reexpand and obliterate the pleural cavity. One of them (W. T.) was in a patient who also had a decortication of the entire lung at the time of segmental resection. In both patients the spaces were obliterated by removing short posterior segments of ribs 4, 3, and 2. The resection in each case had been done through the 5th rib bed.

MAJOR COMPLICATIONS

There were six patients who developed a bronchopleural fistula and were automatically classified as empyemas and reexpansion failures. In only two of these was there evidence of extension. Now one is culture negative after additional surgery, three are persistent (one of these is negative), and two died.

One patient (L. S.) had the left apical-posterior segment removed, developed a bronchopleural fistula which failed to close by a myoplasty and thoarcoplasty. A pneumonectomy was then done. The patient is now well and the sputum is culture negative.

Another patient (G. H.) had the same postoperative misfortune and now has a small bronchopleural fistula after the pneumonectomy. Her sputum is culture negative. She is still very ill, however.

Another patient (J. B.) who had bilateral small cavities developed a bronchopleural fistula after removal of the left apical-posterior segment and has had three attempts at closure by myoplasty and thoracoplasty. We now believe the positive sputum from the opposite chest infects our grafts and working environment which slowly breaks down after each surgical attempt at closure. The next surgical attempt will be directed at the source of the positive sputum in the opposite lung.

Another patient (G. P.) had a contralateral pneumothorax, and it was planned to do an apicosposterior segmental resection if technically possible. Laminographs, however, suggested considerable disease in the anterior segment of the left upper lobe. A preliminary small thoracoplasty was done in view of the possibility of a lobectomy. At operation the decision was changed from a segmental resection to left upper lobectomy. The fissure was obliterated between the apex of the lower lobe and upper lobe because of disease on both sides of it; therefore, the superior segment of the lower lobe was taken rather than divide the fissure. The superior segment in this case was a very large one, and the three remaining basilar segments were entirely too small to fill a reduced but relatively large pleural space. The upper two-thirds became opaque after operation, the tubes plugged, and it was felt that a serosanguineous coag-

ulum had developed which filled the upper chest. On the seventh postoperative day, streptokinase was introduced into the region of the coagulum, and one hour later the patient opened a bronchopleural fistula and spat up about 600 c.c. of serosanguineous material. During the year that followed he developed fluid on the side of the pneumothorax, this became turbid and positive for acid-fast bacilli. Later he developed a homologous serum hepatitis from repeated blood transfusions, re-expanded his contralateral lung, and though his general condition is poor at the present time he is gaining weight at the rate of one pound a week. His sputum is positive and his fistula still open.

Two other patients died, and are reported below.

EXACERBATIONS

Late exacerbations have occurred in five instances. In one instance (A. E.) several months after discharge a small shadow appeared in a follow-up x-ray on a patient whose sputum had been repeatedly negative to culture examinations. The patient was asymptomatic but had one positive sputum culture. The shadow disappeared one month later after administration of streptomycin at home. Sputum cultures are now negative.

Another patient (G. A.) subsequent to discharge developed an intermittently positive sputum culture. Hospitalization, bronchoscopy, x-rays, and laminographs have failed to disclose the source of the positive culture. He is intermittently positive on gastric lavage. This patient has had no prolonged postoperative streptomycin, and probably has a bronchial ulcer beyond the vision of the bronchoscopist.

Another patient (M. D.) with lymphohematogenous tuberculosis and a positive urine had a right upper lobectomy and segmental resection of the superior segment of the right lower lobe. Six months after several negative sputum cultures she reactivated an old lesion in the right lower lobe and became positive. A temporary phrenic crush and pneumoperitoneum failed to change the residual shadow in the right lower lobe. Resection of the right middle lobe and basilar segments of the right lower lobe has converted her sputum cultures.

Two other patients (E. G. and R. F.) have late exacerbations and have not yet cleared on conserative therapy. Neither had streptomycin before, during or after operation.

FATALITIES

One fatality occurred in the first 25 cases. The patient was a 57-year-old man. The operation was easily accomplished, and the patient was considered in good condition twenty-four hours after operation. He requested a glass of water and, a few minutes later upon the nurse's return, respirations had ceased and he was pulseless. Autopsy revealed a collapsed lung on the side of the operation, but the intrapleural tubes had not been clamped post mortem; and breath sounds were heard just prior to death. The patient's family then reported he had had two "heart attacks" prior to the hospitalization which he had not disclosed fearing that the operation would be denied him. A preoperative electrocardiogram was essentially normal.

A second fatality occurred in a healthy 30-year-old man. During the resection of the right apical and posterior segments, the cavity was entered by accident. The intersegmental plane had been destroyed by the inflammatory reaction. In retrospect a lobectomy should have been done. A bronchopleural fistula developed, the lung failed to expand and obliterate the dead space, an empyema occurred, and the patient spread to the lower lobe on the side of the operation. Approximately nine months later a pneumonectomy was done as a desperate gesture to avoid an anticipated fatality. At the end of the operation an anesthetic accident accounted for the patient's death. The outcome might have been the same had the accident not happened.

The third fatality occurred in a 40-year-old patient who had had a *right* 7-rib thoracoplasty subsequent to which he had a bilateral extensive spread. The lungs cleared except for a cavity in the apical-posterior segment of the *left* upper lobe. Function was greatly reduced, and therefore a left extrapleural pneumothorax was done because it could be done under local anesthesia and is a reversible procedure in the first few days. He stood the operation fairly well, and six weeks later a thoracoplasty was laid down to maintain the collapse obtained by the extrapleural pneumothorax. The sputum remained positive, and tomographs disclosed a cavity beneath the thoracoplasty. Functional studies (broncho-spirometry) at this time were borderline. A segmental resection of the apical-posterior segment was done beneath the thoracoplasty. The patient developed a bronchopleural fistula and a small empyema which was drained. He lost ground, gradually became more and more debilitated, and died ten months after operation. The sputum was negative, and autopsy revealed no active disease. Cause of death was respiratory insufficiency. No active disease was present in the specimen and patient's sputum was culture negative at the time of death.

DISCUSSION

INDICATIONS

The indication for this procedure may be inferred from the term segmental resection. In other words, when the main offending focus is well localized to one or two segments, consideration should be given to this procedure. The final decision, however, depends upon many of the same prerequisites used in selecting a patient for lobectomy. Though some of our patients would have been poor candidates for a successful thoracoplasty, many of them would have had a thoracoplasty and probably a successful one in other surgical environments. We must admit, but with some hesitancy, that in localized lesions we are using segmental resection not only instead of, but in preference to a thoracoplasty. Some, of course, are done in conjunction with a thoracoplasty, but the dimensions of the two procedures are much smaller than when only a thoracoplasty is done to control the focus.

The operation is a meticulous one and the statement above must be modified. The morbidity and mortality rates after a thoracoplasty are low in the year 1950. This was not true twenty-five years ago. The morbidity and mortality rates of segmental resection are greatest now. As our experience increased they

became increasingly low. The morbidity and mortality rates in the last forty-one consecutive cases have been comparable in every way to the thoracoplasty figures. Our anxiety now is directed toward the late follow-up results.

In retrospect, our mistakes are obvious and many can be avoided in the future. In the beginning we were cautious in our case selection, and there were few complications in the first twenty-five cases. Then we grew bolder and accepted a few hazardous risks. Our complications and deaths occurred during this period. Upon returning to the well-localized lesion in the patient with resistance our major complications have disappeared for the moment, at least. To establish segmental resection as a reasonable and secure solution in selected cases we wish to emphasize the following principles in management.

LAMINOGRAPHY

Laminography, especially the lateral "cuts," as recommended by Klopstock[14, 15] are essential to accurate evaluation of the disease and its location. Undoubtedly, those who were first engaged in resection therapy made many mistakes because neither laminography nor steroscopic films were used in case selection. Laminography has given us few, if any, false leads. In fact, by crosschecking the surgical specimen with the laminograms our confidence in such studies has increased. Also at the time of segmental resection the palpation of small indolent or active foci is less accurate than serial x-rays and laminographs in determining the activity of a lesion or given focus. On occasions at operation we have changed our decision from segmental resection to lobectomy because of small palpable foci in the anterior segments, only to have the pathologist inform us that the lesions in the questionable segment were firmly and securely healed. At present we are remaining faithful to the preoperative recommendation whenever it is technically possible.

Furthermore, the lateral "cuts" usually outline the fissures and the compensatory spacefilling aspects of the residual segments may be estimated. For example, the position and size of the anterior segment on the right is known as soon as the middle lobe fissures are located; or the size of the apical and posterior segments may be estimated upon identification of the fissure between the superior segment of the lower lobe and the upper lobe. In this series only three patients have not had laminographic studies.

STREPTOMYCIN

Streptomycin was used in 80 per cent of the cases. In selected cases with well localized lesions and little or no sputum streptomycin was not used. The use of streptomycin is designed to accelerate the localization and maturity of a lesion. Its administration before operation must be individualized. Some patients may be prepared in one week, others in three or four weeks. Its use after operation is also variable. In general it should be continued for six weeks to three months after operation. Based upon the work of Meisner, Wilson, and Overholt who demonstrated microscopic intramural tubercles at the point of

bronchial division, it might be used routinely to secure firm healing of the bronchus. Also at the time of segmental resection small indolent or active residual foci may be left behind.

REEXPANSION

Obliteration of the dead space after operation is considered an important principle in the prevention of a tuberculous empyema. Physicians years ago were aware of this principle in the management of a pneumothorax. When an empyema was imminent the lung was quickly reexpanded to avoid maturity of the empyema. It must be assumed that the pleural space is always contaminated during resection therapy, but still the development of an empyema is rare after a segmental resection if this principle is respected.

The dead space cannot be obliterated early after a pneumonectomy, but the pleural cavity, like the peritoneal cavity, can defend itself against a mild infection provided the source of infection is removed or abated. At Sea View Hospital a cavity perforated into the pleural space ten days after a closed intrapleural pneumolysis. The surgical staff of this hospital treated the patient as though an appendix had ruptured. The lobe was resected, and the pleural cavity obliterated immediately by reexpansion of the other two lobes. An empyema did not develop. Though streptomycin was also used, the same result might have been achieved without it. Overholt, for example, before streptomycin was available, has opened cavities and packed them with gauze before proceeding with the operation. He used this technique in large cavities with large amounts of sputum to prevent "spreads." We have accidently broken into cavities during a lobectomy on patients who were either streptomycin fast or were not given it prior to operation, but, if the dead space was obliterated, an empyema did not develop.

The dead space in segmental resection is easily obliterated usually. This is not true, however, if a lobectomy and superior segment is to be removed. In such cases a preliminary "tailoring" of the thorax seems indicated and should be designed to fit the residual healthy components. Obliteration of the dead space after segmental resection is easiest in the first seventy-two hours. Daily x-rays and close attention to the mechanics of the intrapleural suction tubes during this period are paramount.

LOWER LOBE DISEASE

Segmental resection finds its greatest usefulness when the disease is localized to the superior segment of the lower lobe. Disease in this location has been difficult to treat and, though pneumothorax, pneumoperitoneum, cavernostomy, and temporary paralysis of the diaphragm have been successful on occasions, in our experience these procedures have not been consistently reliable. Until segmental resection was tried it was our custom to do either an extensive thoracoplasty or lobectomy, but always with a feeling of dissatisfaction because of the physiologic sacrifice.

FUNCTIONAL ASPECTS

The functional gain by leaving in the anterior segment of the upper lobe is not in itself significant. Its presence as a "filler," however, is thought to be extremely valuable to the function of the other pulmonary components. In segmental resection the degree of pulmonary distention is reduced and there is much less anatomic distortion of the tracheobronchial tree.

The residual lobes after an upper lobectomy are vulnerable to infection, both tuberculous and nontuberculous, because of (1) the angulation of the tracheobronchial tree, and (2) the degree of overdistention. The elongation and foreshortening of the bronchial tree with each respiratory effort, twenty-four hours a day, supported by ciliary action and cough, accounts for our bronchial hygiene. Segmental resection disturbs this balance least.

In some cases of pneumothorax therapy the role of bronchial peristalsis is best appreciated. The bronchus to the immobile lung which has been "trapped" is "dirty" by comparison with the moving opposite lung. The mucosa is often covered by a thin white or grayish precipitate which wipes off and leaves a red congested mucosa beneath. This was noticed in the "trapped" lung in nontuberculous war injuries as well. Upon reexpansion, however, normal hygiene is restored. Bronchial peristalsis is on duty continuously, and its protective importance cannot be overemphasized. The emphysematous lung with the patient in a prolonged inspiratory state cannot foreshorten the chronically elongated bronchial tree, and almost all emphysematous patients experience, therefore, frequent episodes of pulmonary suppuration, and have variable amounts of bronchiectasis.

SUMMARY

Segmental resection in pulmonary tuberculosis is designed to remove the major pathologic focus with little physiologic sacrifice. Resistance and localization are essential to the desired result. Streptomycin not only accelerates maturity of the lesion, but may aid in bronchial healing.

Cavitary pulmonary tuberculosis in man is a disease confined usually to the apical and posterior segments of the upper lobes and the superior segments of the lower lobes. Laminography, especially the lateral "cuts," is paramount to accurate localization of the lesion. As the lesions heal and contract, slow compensatory distention occurs in the normal lung components. After segmental removal the additional distention is slight and of little significance.

The operation is a meticulous one, requires close vigilance in the early postoperative period, and if the dead space is obliterated by early reexpansion of the lung, complications rarely occur. For this reason when a lobectomy and segmental resection are contemplated, one of five methods should be used to assure obliteration of the dead space.

Three patients died, but the operation as such was responsible for only one. In the seventy-five cases, sixty-five (86.7 per cent) were culture negative, but the follow-up period was short. Only two spreads occurred in the entire series,

but six developed bronchopleural fistulae. Two of the latter are dead, two required additional surgery for closure, and two persist. Five late exacerbations have occurred—they are not extensive.

In the last 41 consecutive cases no major complication has occurred. Segmental resection has several advantages over a thoracoplasty for the same type of lesion, and we believe that careful selection and increasing experience may prove it to be the superior procedure.

(See discussion on page 875.)

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RESECTION IN THE TREATMENT OF PULMONARY TUBERCULOSIS

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INCREASING indications for resection in the treatment of pulmonary tuberculosis emphasizes the need for careful appraisal of its effectiveness in controlling the disease and of the hazards incident to its use. With better surgical and anesthetic techniques the trend is toward lower morbidity and mortality rates but even with streptomycin protection they are still much too high. A recent report by Sweet[1] concerning the late results of resection in 63 patients treated in the pre-streptomycin era presents an especially pessimistic view of the range of usefulness of resection. Of 27 patients who had lobectomy, 9, or 33 per cent, are dead; 6, or 22.2 per cent, are alive with evidence of active disease; and 12, or 44.4 per cent, are apparently well. In the pneumonectomy group of 36 patients, 19, or 52.8 per cent, are dead; 3, or 8.3 per cent, are alive with active disease; and 14, or 38.9 per cent, are apparently well.

In 1947, Overholt and associates[2] reported a series that is representative of the early streptomycin era. Of 35 lobectomies, 11 per cent are dead, 57 per cent are clinically well with negative sputum, and 20 per cent were too recently done to classify. Thirty-three, or 48 per cent, of 69 pneumonectomies were living and well with negative sputum; 17 per cent were dead and 16 per cent were too recent to classify. They also point out the greatly decreased incidence of spread of disease and bronchopleural fistula. Although this lower incidence of complications must be largely attributable to streptomycin protection, the advantage of the face-down position is thought to be a factor of considerable importance.

Bailey and co-workers[3] in 1949, reported a comparison of results in 100 resections without streptomycin and 100 resections with streptomycin. A marked reduction of contralateral tuberculous spread and tuberculous empyema was noted in the streptomycin treated patients. They also observed a marked reduction in mortality in the patients with acute pneumonic disease and extensive lung destruction in the streptomycin group.

The results of the tuberculous resections done at the Mayo Clinic were reported in 1948 by Clagett and Seybold.[4] There were 2 early deaths and 1 late death in 15 pneumonectomies and 1 late death in 14 lobectomies. Five had active disease and 1 was untraced at the time of the report. Early spread occurred in 2 pneumonectomies (13.3 per cent). Late spread occurred in 4 lobectomies (28.6 per cent) and 2 pneumonectomies (13.3 per cent). Two pneumonectomies developed bronchopleural fistula. Tuberculous empyema occurred in 1 lobectomy and in 1 pneumonectomy. One pneumonectomy was complicated by a nontuberculous empyema.

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Gale, Dickie, and Curreri[5] recently reported the results of 80 resections with an operative mortality of only 2.5 per cent and a total fatality rate of 6.25 per cent, 83.75 per cent were negative and clinically well for varying periods up to three years following operation. Ipsilateral reactivation or spread occurred in only 2 instances and contralateral spread in six. There were no bronchopleural fistulas in 47 pneumonectomies and only 2 in 33 lobectomies, 1 of which was classified as temporary, the other causing death. The chief indications in this series were thoracoplasty failure, 51.25 per cent, and bronchostenosis, 26 per cent. Of the 31 thoracoplasty failures, 26 had pneumonectomy and 15 had lobectomy.

CLINICAL MATERIAL

This report deals with the results of resections for pulmonary tuberculosis performed in our clinic from 1945 to Nov. 1, 1949. Prior to 1945, only occasional resections were done for pulmonary tuberculosis and with few exceptions were done by means of the tourniquet technique. Consequently, they have little statistical significance and are not included in this report.

TABLE I. RESECTION FOR PULMONARY TUBERCULOSIS

202 OPERATIONS	
Lobectomy	98
Pneumonectomy	104
Total	202

TABLE II. TYPE OF OPERATION BY SIDE

Lobectomy		
Right	65	
Left	33	
		98
Pneumonectomy		
Right	55	
Left	49	
		104
Total		202

There were 202 operations performed upon as many patients, 98 of which were lobectomies and 104 of which were pneumonectomies. Lobectomies were done on the right side in 65 instances and on the left in 33 instances. There were 55 right pneumonectomies and 49 left pneumonectomies.

Only 9 segmental resections were done in the entire series. In most instances they were not deliberately planned but were believed necessary when possible to avoid pneumonectomy when disease occurred in segments contiguous to lobes in which the lesion was originally localized. In 11 of the postthoracoplasty resections lobectomy was done in an effort to preserve space-filling lung tissue even though the lobe or lobes allowed to remain were not always entirely free from palpable disease.

One hundred and nineteen of the patients were female and 83 were male. There were 36 (18 per cent) Negroes, 30 of Polish extraction, 4 Mexicans, and one American Indian. Mention is made of the rather large percentage of these racial groups because of their known poor response to the disease.

The youngest patient was 6 years of age and the oldest 73. Twenty-two were 50 years of age or over and 2 were in the seventh decade of life.

There was clinically significant contralateral disease in 87, or 43 per cent, of the patients. In 60 it was considered minimal or moderate in extent and in 27 it was extensive. In the latter group 4 had cavity and 10 had re-expanded pneumothoraces.

Since streptomycin became available it has been used for preparation of patients for surgery and for protection during the postoperative phase. It has been a useful adjunct to operation but, as is well known, its use is not always attended by success and certainly its misuse is occasionally attended by disaster.

INDICATIONS FOR RESECTION

The selection of lesions suitable for resection has been fairly well standardized as regards certain major classifications. Such obvious indications as failure of thoracoplasty, the presence of high-grade bronchostenosis and associated bronchiectasis are widely accepted. In this series there were 71 thoracoplasty failures (35 per cent), 33 with bronchostenosis (16.3 per cent), and 14 (7 per cent) in whom the primary indication was tuberculous bronchiectasis. The true incidence of bronchostenosis is not indicated in Table III because of the inclusion of at least 8 additional instances under the thoracoplasty failures.

TABLE III. INDICATIONS FOR RESECTION

Thoracoplasty failure	71
Bronchostenosis	33
Tuberculoma	26
Lower lobe disease	22
Tuberculous bronchiectasis	14
Disease not suitable for thoracoplasty	9
Destroyed lung	4
Post lobectomy fistulo and empyema	1
Other indications	22
Total	202

Tuberculoma as an indication must be considered slightly controversial largely because of definition. There were 26 in this classification, or 12.8 per cent. These are represented mainly by the solitary round or conglomerate lesions with or without evidence of cavity, and by the so-called "filled" cavity. They are considered to be encapsulated caseous lesions with or without central liquefaction and/or bronchial communication. Also included in this group are a few instances of multiple encapsulated caseous foci limited to a lobe. Four additional cases originally thought to be tumor bring the total in this group to 30 or almost 15 per cent of all resections.

TABLE IV. OTHER INDICATIONS

LESIONS RESECTED—LATER PROVED TUBERCULOUS	
Peripheral round lesion	4
Atelectasis with negative sputum	10
Abscess or suppurative pneumonitis	4
Bronchiectasis	4
Total	22

Lower lobe disease, long recognized as frequently uncontrollable by the usual collapse measures, is a logical extension of the indications for resection. In this category, without any effort to further classify type of disease, are included 22, or 10.9 per cent. In this group is to be found the ubiquitous and troublesome superior division lesion of the lower lobe.

Perhaps the most controversial of the indications is the upper lobe lesion for which thoracoplasty is ordinarily considered the procedure of choice. We believe that lobectomy should not be substituted for thoracoplasty where there appears to be reasonable chance for success with thoracoplasty and when there is not an obvious contraindication to thoracoplasty. We have selected 9 instances, 4.5 per cent, in which either the disease or patient were considered not suitable for thoracoplasty.

A few of these are children with progressive upper lobe disease, one an adult with pectus excavatum, and the remaining are tension cavities, or other lesions in which thoracoplasty failure seemed inevitable.

Destroyed lung is seldom considered an indication for primary resection except when due to high-grade stenosis. Thoracoplasty is thought to be the procedure of choice and is followed by resection in the event of thoracoplasty failure.

There was one patient who had had a lobectomy followed by fistula, empyema, and persistently positive sputum in whom pneumonectomy was completed.

TABLE V. COMPLICATIONS

202 RESECTIONS FOR PULMONARY TUBERCULOSIS	
Pleural	
Fistula and empyema	27
Hematoma*	5
Pericardial	
Effusion	2
Constrictive pericarditis	1
Adhesive pericarditis	1

*Two required secondary operation and evacuation of clot.

The other indications as noted in Table IV represent lesions which were thought to be tumor or suppurative disease prior to operation but in which the true nature of the disease was established by the microscopic sections. There were 22, or 11 per cent, in which the preoperative diagnosis was incorrect.

TECHNIQUE OF OPERATION

The Overholt face-down position is used routinely except for the occasional patient with a tuberculoma or other lesion from which minimal drainage of secretions is anticipated.

During the past one and one-half years anesthesia has been induced with pentothal and curare and maintained with intravenous procaine and endotracheal nitrous oxide and oxygen. Prior to the institution of this practice, the anesthetic agent used was endotracheally administered ether vapor and oxygen.

The pleural cavity is entered through the periosteal bed of the appropriate rib. The lobe or lung is mobilized by separation from the parietes with sharp

dissection care being taken to avoid entering subpleural cavities or caseous foci of disease. The structures at the hilum are dissected individually, the vascular elements are ligated with silk, the bronchus is amputated, and the stump closed with end sutures of fine silk. The stump is covered with parietal pleura or other contiguous tissue whenever possible.

All lobectomies have one or more thoractomy tubes placed in the pleural cavity and attached to water-seal drainage bottles until expansion is effected. The pneumonectomies are not drained. Pressures in the pleural space are maintained at optimum levels and streptomycin and penicillin are introduced by frequent insertion of the aspirating needle. Careful attention to blood replacement and fluid requirements is of course extremely important. Early ambulation and the maintenance of strict vigilance as regards the evacuation of tracheal secretions contribute importantly to an uncomplicated postoperative course.

COMPLICATIONS

The development of bronchopleural fistula and empyema was by far the most important and disastrous complication. Since empyema associated with fistula in the tuberculous are nearly always secondarily infected tuberculous empyemas, no effort was made to distinguish between tuberculous and nontuberculous empyema. In all except one instance, a fistula could be demonstrated in the empyemas complicating resection in this series.

This very serious complication occurred in 27, or 13 per cent, of the patients and was a major cause of death. In 5 patients resection was undertaken under conditions that were favorable for the development of fistula and empyema. In 3 of these empyema was already present and in 2 there were persistent bronchocutaneous sinuses following cavernostomy.

Pleural hematoma occured in 5 patients. Secondary thoracotomy was necessary for the evacuation of clot in 2 of these. Absorption of the hematoma occurred in the others.

Pericardial effusion was a late complication which contributed to death in 1 patient with disseminated tuberculosis and empyema. Another patient with pericardial effusion and ascites is doing poorly many months following operation. A third patient developed a constrictive pericarditis and required pericardectomy. There was one instance of adhesive pericarditis. In all of these, it was noted that the pericardium was accidentally opened at operation.

TABLE VI. COMPLICATIONS IN BRONCHOPLEURAL FISTULAS PRESENT STATUS ACCORDING TO SIDE AND TYPE OF OPERATION

	LOBE		PNEUMONECTOMY		
	RIGHT	LEFT	RIGHT	LEFT	TOTAL
Well	2	0	1	0	3
Sick					
Improving	1	3	3	1	8
Worse	1	1	2	1	5
Dead	1	1	8	1	11
Total	5	5	14	3	27

In Table VI it is noted that the incidence of bronchopleural fistula is much higher in the right pneumonectomies. This is attributed to the fact that the

TABLE VII. COMPLICATIONS

202 RESECTIONS FOR PULMONARY TUBERCULOSIS		
Spread and/or exacerbation		
Following lobectomy		
Contralateral	8	
Ipsilateral	8	
		16
Following pneumonectomy		11
Total		27*

*Both ipsilateral and contralateral in 2 patients.

TABLE VIII. SPREADS OR EXACERBATIONS OF CLINICAL SIGNIFICANCE IN 202 RESECTIONS FOR PULMONARY TUBERCULOSIS

Resulting in death		
Associated with bronchopleural fistula	11	
Without fistula	1	
		12
Continuing morbidity		
Growing worse	5	
Improving	8	
		13
Total		25

TABLE IX. PRESENT STATUS IN 202 RESECTIONS FOR PULMONARY TUBERCULOSIS

	NUMBER	PER CENT
Home	120	59.4
Hospital	57	28.2
Dead	25	12.4
Total	202	100.0

TABLE XI. DEATHS IN 202 RESECTIONS FOR PULMONARY TUBERCULOSIS

	LOBECTOMY	PNEUMONECTOMY	TOTAL
Postoperative	2	12	14
Late	4	7	11
Total	6	19	25

TABLE XI. DEATHS ACCORDING TO INDICATION FOR OPERATION

	NUMBER OF OPERATIONS	DEATHS	PER CENT
Thoracic failure	71	9	12.7
Bronchostenosis	33	4	27.1
Tuberculoma	26	0	0
Lower lobe disease	22	5	22.7
Mistaken diagnosis	22	4	18.1
Bronchiectasis	14	1	7.1
Not suitable for thoracoplasty	9	0	0
Destroyed lung	4	1	25.0

left bronchial stump is retracted to a more protected position beneath the aortic arch and buried in mediastinal tissue.

Transbronchial spread of disease or exacerbation of disease was the next most frequent complication and was frequently associated with bronchopleural

TABLE XII. CAUSES OF DEATH

	EARLY	LATE
Cardiac arrest	1	
Hemorrhage	3	
Shock	1	
Transfusion reaction	2	
Pulmonary insufficiency	4	
Progressive disease without fistula	1	
Bronchopleural fistula with empyema and progressive disease	2	9
Pericarditis		1
Nontuberculous disease		1
Total	14	11

TABLE XIII. SURVIVAL PERIOD

Six months or less	17
6 to 18 months	71
1½ to 2½ years	48
2½ to 3½ years	26
3½ to 4½ years	13
Over 4½ years	2
Total	177

TABLE XIV. PRESENT SPUTUM STATUS

	NUMBER	PER CENT
Negative (culture)	150	84.75
Positive	27	15.25
Total	177	100.00

fistula. It occurred in 14, or 14 per cent, instances in the lobectomy group with equal distribution between the two sides. It followed pneumonectomy in 11, or 10.5 per cent. In 2 patients spread or exacerbation occurred on both sides.

Further analysis of spreads or exacerbations of disease reveals that 12 results in death, 11 of which were associated with bronchopleural fistula. Thirteen were responsible for continuing morbidity. Of the 13 living patients in whom spread occurred, 8 are improving and 5 are becoming worse.

The following miscellaneous group of complications was encountered:

Tuberculous infection of chest wall	1
Chest wall sinuses	2
Wound dehiscence	1
Contralateral spontaneous pneumothorax following pneumonectomy	1
Temporary paresis of left recurrent laryngeal nerve	1
Laryngeal stridor due to a subglottic inflammatory membrane	1
Ulceration of bronchial stump	3

RESULTS

Of 202 patients who had resection for pulmonary tuberculosis, 120, or 59.4 per cent, are home; 57, or 28.2 per cent, are still in the hospital, and 25, or 12.4 per cent, are dead.

There were 14 operative deaths, a fatality rate of 6.9 per cent and 11 late deaths, or 5.5 per cent.

TABLE XV. PRESENT CLINICAL STATUS
HOSPITAL

	LOBECTOMY	PNEUMONECTOMY
Clinically well and negative	15	13
Ill or incapacitated		
Negative with pleural complications	2	2
Negative, respiratory cripple		3
Positive		
Fistula, empyema and/or spread	5	3
Spread or exacerbation	5	1
Previous contralateral disease	1	1
Stump ulcer	1	1
Source not determined	1	3
Total	30	27

TABLE XVI. PRESENT CLINICAL STATUS

177 PATIENTS HOSPITAL		
Clinically well		
Negative	28	35
Ill or incapacitated		
Negative with pleural complication	4	
Negative, respiratory cripple	3	
	—	35
Positive		
Fistula, empyema and spread or exacerbation	8	
Spread or exacerbation alone	6	
Previous contralateral disease	2	
Stump ulcer	2	
Source not determined	4	
	—	22
Total		57

TABLE XVII. PRESENT CLINICAL STATUS
HOME

	LOBECTOMY	PNEUMONECTOMY
Clinically well		
Negative	59	53
Negative with pleural complications		1
Occasional positive culture	2	
Ill or incapacitated		
Negative, respiratory cripple		2
Positive	1	2
Total	62	58

TABLE XVIII. PRESENT CLINICAL STATUS

177 Patients HOME	
Clinically well	
Negative	112
Negative with pleural complications	1
Occasional positive culture	2
Ill or incapacitated	
Negative, respiratory cripple	2
Positive*	3
Total	120

*Source: contralateral disease, 1; stump ulcer, 1; not determined, 1.

Of 104 pneumonectomies, 19 are dead, a total fatality rate of 18 per cent, whereas in the lobectomy group only 6 are dead, a total fatality rate of 6.1 per cent.

Table XI, which records the deaths according to indications for operation, reveals fatality rates near the mean figure of 12.4 per cent for; thoracoplasty failure and bronchostenosis. There were no fatalities in the tuberculoma group or in the group thought unsuitable for thoracoplasty. In the other categories fatality rates are distorted by the small number involved and are not statistically significant.

The causes of death are listed in Table XII.

As noted previously bronchopleural fistula and empyema in association with progressive disease was the most significant single factor in the fatality statistics, accounting for almost one-half of the deaths. This serves to emphasize again that the ultimate fate of the patient is largely determined by the status of the bronchial stump.

One death was due to cardiac arrest, 3 to hemorrhage, and 1 to shock. Two patients died as a result of transfusion reactions. In 4 pulmonary insufficiency was considered the cause of death. One patient died following pericardectomy for constrictive pericarditis. She also had a previously undiagnosed mitral stenosis. One death resulted from early massive spread without fistula. One late death occurred as a result of nontuberculous disease.

The time elapsed since operation is indicated in Table XIII. A majority of the patients have been operated upon within the past three years.

Table XIV records the present sputum status of 177 patients.

Tables XV, XVI, XVII, and XVIII show the present clinical status of living patients. Follow-up has been possible in all patients. It will be noted that of the patients now in the hospital nearly all of those listed clinically well and negative can reasonably be expected to move into the same classification in the home group. The fate of the positive group is predictable only in so far as those with bronchopleural fistula and progressive disease are concerned. It is estimated that at least 5 of these will die. The fate of the remaining patients is indeterminate, though it seems likely that most of them will live and several may become clinically well and negative.

Of 202 patients who had resection for pulmonary tuberculosis, 120, or 59 per cent, are home; 112, or 55 per cent, being clinically well and negative. Estimated on the basis of 177 living patients, 68 per cent are home, clinically well and negative.

DISCUSSION

There is little difference of opinion as regards the indications for resection except in the upper lobe lesions in which thoracoplasty would ordinarily have been employed. However, certain types of lesions have proved resistant to collapse by thoracoplasty and consequently are thought to be better treated by

resection. The following types of lesion are representative of those in which resection is preferable to thoracoplasty.

1. Tension cavities. Thoracoplasty is frequently ineffective in closing tension cavities even when carried out with streptomycin to control associated bronchial disease and stenosis. Because of inability to predict a satisfactory response to thoracoplasty resection is frequently considered preferable.

2. Lesions which appear in the roentgenogram as scattered nodular infiltrates with fibrosis and indistinct areas of rarefaction suggesting small cavities, whether extensive or occupying a limited area. These lesions, the familiar fibrocaseous adult lesion, are usually found to be firm and inelastic and represent multiple areas of poorly encapsulated caseation with interspersed fibrosis. There is almost always demonstrable one or more small liquified areas of caseation which communicate with a small bronchus. Such lesions are very frequently much more extensive than their radiologic appearance would suggest and are resistant to any form of collapse.

3. Lesions so situated within the lobe as to require extensive thoracoplasty with needless sacrifice of pulmonary function.

4. Some giant cavities, especially in the gutter.

5. Progressive caseous pneumonic disease in children or young adults limited to an upper lobe. In fact, in all children resection is preferable to thoracoplasty.

6. Tuberculoma or tuberculoma-like lesions, in themselves prime indications for resection whenever localized to a lobe or segment should never be subjected to thoracoplasty or other collapse measures when located in an upper lobe. With very few exceptions these lesions should be resected. Even the presence of calcium is not always an indication of their benignity either from the standpoint of tumor or tuberculosis.

The lower lobe lesion, which has not responded well to collapse measures, is a logical indication for resection. It is questionable whether resection should be delayed for any but the briefest trial of other measures if the lesion is extensive. Obviously smaller infiltrates without cavity or larger exudative infiltrates which tend to clear should have a longer trial of bed rest and collapse before the decision is made to resect. Such obvious indications as the persistence of a lesion with positive sputum, evidence of associated bronchiectasis, tension cavity, filled cavity, or the presence of single or multiple encapsulated caseous foci, will dictate resection.

There is still another group of patients in whom the need for resection is anticipated but who, for one reason or another, should have thoracoplasty as the primary procedure. The prime example of this situation is the extensively involved lung or upper lobe in a patient who is in precarious immunologic balance. Thoracoplasty in such a situation will often throw the balance in favor of the patient and set the stage for resection. Thoracoplasty may in some instances even prove effective in controlling such lesions. Thus a sequence of events will have transpired which will render resection less hazardous and even in a few instances unnecessary.

A further benefit is thought to accrue as a result of this plan by reducing the space available for occupancy by the remaining lobe or lobes if a lobectomy has been done or making an empyema a less serious complication in the event that infection supervenes or the bronchus opens following pneumonectomy.

One of the most important factors determining the success of resection in pulmonary tuberculosis is adequate healing of the bronchial stump. Failure of healing in the early postoperative course, if not attributable to ineffective closure or streptomycin resistance, may be due to mucosal disease, though numerous instances have been noted in which adequate healing occurred when transection was carried through grossly diseased mucosa. The late occurrence of fistula would seem to be related to contiguous infection in the pleural space. The latter can be minimized by avoidance of gross contamination whenever possible by carrying the dissection into the extrapleural plane. However, contamination is unavoidable in many instances despite the most skillful manipulations and probably occurs much more frequently than is apparent from gross inspection.

The fear of streptomycin resistance has been lessened by experimental and clinical evidence that the combination of PAS and streptomycin has successfully delayed or prevented the development of emergence of significant resistance. This is particularly important in cavitary lesions which often require resection. Closer cooperation between medical and surgical departments in the management of antibiotic therapy in the acutely ill patient in preparation for later surgery should result in fewer resistant patients and consequently render surgery less hazardous in this salvage group.

That further expansion of the area of usefulness of resection will occur is quite likely. However, thoracoplasty continues to be a highly effective measure for the control of a large number of upper lobe lesions and will probably maintain a prominent if not the commanding position it has enjoyed as the most universally effective major surgical procedure. Its limitations as regard the control of certain types of lesions must be more clearly defined. A better correlation of the radiologic appearance with the pathologic characteristics of the lesion should be the basis for selection of the appropriate procedure.

SUMMARY

The results of resection in 202 patients with pulmonary tuberculosis have been presented. There were 98 lobectomies and 104 pneumonectomies.

Bronchopleural fistula with empyema occurred in 27, or 13 per cent, of the patients and was the major cause of death. Spread or exacerbation of disease occurred in 14 per cent of the lobectomies and 10.5 per cent of the pneumonectomies.

Fourteen patients died following operation and eleven died later, a total fatality rate of 12.4 per cent. One hundred and seventy-seven patients are living six months to five years following operation. One hundred and twenty, or 68 per cent, of these are home and clinically well.

One hundred fifty, or 85 per cent, of the survivors have negative sputum or gastric washings on culture.

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(See discussion on page 875.)

LOBECTOMY AND PNEUMONECTOMY IN THE TREATMENT OF PULMONARY TUBERCULOSIS

A TEN-YEAR SURVEY

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INTRODUCTION

PULMONARY resection is a method of treatment of tuberculosis which has gained increasing attention in the past several years. The report of Churchill and Klopstock[1] indicated the potential use of the procedure. The reports of Maier[2] and Sweet,[3] in 1946, indicated that early results deteriorated in the later follow up and Sweet[4] recently has reported his group again "as showing that extirpative surgery is a procedure of limited usefulness in the management of the disease." Overholt and his group[5,6] have demonstrated the results in a considerable series of patients. Their experience covers the period since 1934, and they have added the use of streptomycin and upper thoracoplasty in their later cases. Their reports stress the good results, particularly in the face of difficult problems of therapy and several reports[7,8,9,10] have indicated the value of streptomycin in the preoperative and postoperative period. This study was undertaken at Bellevue Hospital to evaluate our experiences for further use of the procedure.

MATERIAL

The seventy-three cases in this report include all patients on the Bellevue Hospital Chest Surgical Service in the period 1939 to October, 1948, on whom a resection was done for pulmonary tuberculosis. The records of the pathology department were reviewed and all surgical specimens of lung tissue in which a diagnosis of tuberculosis was made were checked against the former group. The charts were then reviewed and if tuberculosis was not of clinical significance, the cases were omitted from this study. Four cases from the Chest Surgical Service of the Veterans Administration Hospital, Bronx, N. Y., are included.

An attempt was made to follow all patients at regular intervals and an effort to review all of the group was made recently. Two have never returned for a follow-up visit.* The remainder were seen by one of the authors during 1950, or recent roentgenograms were reviewed and present status determined by letters from their physicians.

Lobectomy was performed on forty-two patients and thirty-one had a pneumonectomy. There were twenty-eight upper and fourteen lower lobe

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*The patient with pneumonectomy was located recently and a roentgenogram seen. She has endobronchial disease in the remaining lung.

resections, and seventeen right and fourteen left pneumonectomies. One classified as a pneumonectomy had only ligation of a vessel; resection was abandoned because of poor condition at that time, and death occurred on the forty-eighth postoperative day. Once pneumonectomy was performed three years after a tourniquet lobectomy for bronchiectasis because of the development of tuberculosis in the residual stump of lung. There were no segemental resections. In most instances the operator was the resident thoracic surgeon, although a member of the attending staff was always present and decided on the advisability and the extent of the pulmonary resection. The cases were fairly evenly distributed among the ten members of the attending staff.

RESULTS

Lobectomy.—In Table I a summary of the results in the lobectomy group is given listing the year each patient was operated upon. The results are classified by groups: clinically well, alive with active disease, died. The thirty-one listed as clinically well have negative sputum and developed no new lesions in the follow-up period. Two patients included in this group showed a minimal exacerbation of old lesions which promptly subsided and have remained unchanged for at least two years. Four in the group are alive with active disease; one developed a cavity in the lower lobe on the operated side, the others have new infiltrates which appeared after two years of observation. There were six deaths. One patient was not followed.

The indication for operation is given in the subheadings. Lobectomy was undertaken as the primary method in the first group. In the second, thoracoplasty was performed. The disease later progressed and excavated under the collapse. Six months to several years followed the original operation before resection was undertaken. The third group includes those for whom a thoracoplasty and lobectomy were planned before either procedure was undertaken. The collapse was the first operation in one-half of these. When it followed resection it usually was done two to three weeks later. These were all four or five-rib posterior thoracoplasties leaving transverse processes in place and in a few, the first rib was not removed. Scoliosis was not seen in the group. There were several patients in the first and third groups on whom thoracoplasty might have been tried as a sole therapeutic method for upper lobe disease. In a case by case review of the material, we believe that the results obtained so far by combining limited thoracoplasty with resection and streptomcyin have been as good or better than might have been anticipated in the same period by the use of collapse therapy alone.

Twelve lobectomies were done prior to 1947. More recently, after streptomycin became available, it has been given to all patients undergoing resection when tuberculosis was diagnosed. Ten of fourteen patients had a thoracoplasty in an attempt to prevent overdistention after upper lobe resection. The question of thoracoplasty arose in the others only after the histopathologic report on the resected specimen showed tuberculosis. Since the lungs then were well expanded and presumably adherent, it was felt that thoracoplasty would collapse a small segment and leave the remainder of the lung distended. After lower lobe lobec-

TABLE I. RESULTS IN 42 LOBECTOMIES FOR PULMONARY TUBERCULOSIS

		TOTAL	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939
Lobectomy no thoracoplasty	Not followed	1		1								
	Clinically well	11	5[A]	2[B]			2		1			1
	Alive with active disease	2	2[C]									
	Died	4				1	1	2				
Lobectomy for thoracoplasty failure	Clinically well	11	3	5				2		1		
	Alive with active disease	2	1	1								
	Died	1								1[E]		
Planned[d] lobectomy and thoracoplasty	Clinically well	9	8	1								
	Alive with active disease	0										
	Died	1	1									

A. Four were lower lobe resections one of which had a phrenic crush.

B. One was lower lobe resection.

C. One patient had a phrenic crush after lower lobe lobectomy.

D. One thoracoplasty after lower lobe lobectomy consisted of removal of ribs seven to ten, two were ribs two to four, the others were upper four or five rib thoracoplasties.

E. Patient died in 1945.

TABLE II. CAUSES OF DEATHS IN 6 PATIENTS AFTER LOBECTOMY FOR TUBERCULOSIS

DATE OF LOBECTOMY	TIME OF DEATH	COMMENT	CAUSE OF DEATH
1941	4 years	Tourniquet lobectomy LLL for tuberculosis. Developed bronchopleural fistula, empyema, and slowly progressive pulmonary tuberculosis	Extensive tuberculosis
1943	22 months	Lobectomy undertaken with diagnosis of lung abscess. Specimen showed fibrocaseous tuberculosis with cavitation. Died in sanatorium. Autopsy showed widely disseminated tuberculosis	Extensive tuberculosis
1943	18 days	Lobectomy for tuberculosis, large tension cavity which emptied suddenly on operating table, inundating airway. Massive bilateral spread and bronchopleural fistula. Autopsy: tuberculosis in wound, pleura, lung, appendix	Extensive tuberculosis
1944	59 days	Lobectomy for large tuberculosis cavity. Disease tissue sectioned at operation Postoperative bronchopleural fistula, bilateral spread, and terminal hemoptysis	Extensive tuberculosis and hemoptysis
1945	3 hours	Lobectomy for suppurative disease, specimen showed cavity with fibrocaseous tuberculosis. 3 preoperative cultures for tuberculosis returned positive postoperatively Autopsy: fibrocaseous tuberculosis in opposite lung. Cause of death, hemorrhage into pleural cavity	Hemorrhage
1948	1 year	Upper lobe tuberculosis, pneumothorax, pneumolysis, acute empyema, and bronchopleural fistula following lysis. Admitted to Bellevue. Drainage upper thoracoplasty, streptomycin, drained. Lobectomy and decortication, localized empyema in apex of chest. Progessive tuberculosis of anterior chest wall, lungs clear. Depression. Inanition	Extensive pleural tuberculosis

tomy, phrenic crush was done in two patients: in one on the tenth and in the other on the fourteenth postoperative day. A thoracoplasty removing ribs seven to ten was performed following one recent lower lobe lobectomy. In four instances the lower lobe was small and shrunken and it was presumed that intrathoracic adjustment of the remaining lung tissue had already occurred.

Table II is a summary of the six deaths (14 per cent) in this group of forty-two lobectomies. Five of these occurred prior to 1945; the one since 1945 was a very poor operative risk. All of the mortalities except one were due to uncontrolled tuberculosis; one was due to an error in technique.

It is impossible to analyze forty-two cases statistically. The results obviously are influenced by the extent of parenchymal involvement, character and amount of sputum, and disease in tissue remaining after lobectomy. In several patients, tuberculous lesions were known to have been left after resection. Many of these foci were not seen by x-ray examination but were palpated at operation. It is now assumed that with resection, only a major focus of disease is to be removed and that all patients still have a tuberculous lesion which requires further therapy.

As noted previously, streptomycin has been used in all patients since 1947. Repeat courses of the drug were instituted in several instances. It is our clinical impression that the agent has been extremely useful in the control of active disease so that the process eventually was confined to one lobe with other areas regressed and quiescent. Resection under these circumstances removed the major focus. It was amply demonstrated in the reports prior to 1946 that resection in tuberculosis could be done without streptomycin and usually without immediate difficulty. We have no direct evidence of the efficacy of streptomycin used as a protective agent during the operative and postoperative period. We feel justified in using it during this time on the basis of present clinical experience, since this may be the critical period in the evolution of the disease by spread or exacerbation of quiescent lesions.

Pneumonectomy.—In Table III the results are listed in the pneumonectomy group. Nineteen patients are clinically well; two had questionable activity. In one, there appeared thin-walled cavities which cleared rapidly and his sputum was never positive. In retrospect they appear to have been emphysematous areas. There are three patients* who are alive with active disease, obviously a more serious complication after pneumonectomy than after lobectomy. The indications for operation are listed in Table III and are self-explanatory. The thoracoplasty failures are similar to those in the lobectomy series except for the extent of the disease.

Deaths.—in Table IV the nine deaths (29 per cent) in the pneumonectomy group are summarized. Four occurred in the eight cases operated upon prior to 1945, and five since that time in twenty-three cases. Tuberculosis was not the cause of death in the four most recent fatalities.

There is less disagreement about the indications for pneumonectomy than for lobectomy since in the pneumonectomy group, in most instances, the operation was the only procedure that might favorably influence the course of the disease.

*Including the patient recently located, listed in the table as not followed.

Again, the group cannot be looked at statistically. The statements that have been made on the use of streptomycin with lobectomy apply even more strongly in the pneumonectomy group.

DISCUSSION

The review of the cases in this study was undertaken to evaluate our criteria regarding the indications for resection. It is now generally accepted that lobectomy is frequently indicated in treating lower lobe cavities, stenosing endobronchial disease, and thoracoplasty failures. The indications for pneumonectomy usually are well defined and cause little controversy, except for those patients with extensive unilateral caseating disease with normal appearing contralateral lung. The main differences of opinions among clinicians arise in discussing those cases of tuberculosis that might be candidates for thoracoplasty.

The surgical principle of resection of tuberculous tissue has been accepted for such lesions as tuberculous lymph nodes, genitourinary tuberculosis, and ileocecal tuberculosis. In none of these instances is it presumed that all tuberculous tissue is removed. Usually only a major focus is extirpated after the individual has shown some evidence of ability to control these and other lesions and when the focus to be resected does not regress. In the same sense, the tissue removed by resections is only an active dominant portion of the disease and frequently nodules are palpated in areas left in situ. This was emphasized by Sweet[3] in his original report. The question arises as to whether the procedure carries a late deleterious effect for the lesions which remain or increases the danger of new foci appearing. The reports based on experiences prior to 1946[2,3] seem to indicate that such danger does exist. There is some evidence too that overdistention has an unfavorable effect on pulmonary tuberculosis especially if one interprets the late results of the early series[2,3] of resections in this light. It seemed wise, therefore, to re-evaluate pulmonary resection undertaken with specific antimicrobial therapy and combined with some technique to prevent overdistention of the remaining tissue.

A limited four- or five-rib upper thoracoplasty is used to prevent overdistention after upper lobe removal, and it is thought that in many instances this preserves space available for functioning lung tissue when compared to the usual six- or seven-rib thoracoplasty. It is believed that this should be done before or concomitant with the lobectomy to permit the lung to adjust to the space before pleural adhesions limit its mobility. When it is long delayed after resection, the effect may be only to collapse the apex, leaving the remainder overdistended.

Phrenic crush was used a few times following lower lobe lobectomy to achieve a decrease in the volume of the hemithorax. It was done after complete re-expansion had occurred and the diaphragm was not required for cough. Upper thoracoplasty has been suggested following lower lobectomy because, after phrenic interruption, the loss of the motion of the diaphragm is temporary and it limits function, and lower thoracoplasty may not give satisfactory collapse and may interfere with the motion of the diaphragm.

The clinical impression based on the material summarized in this report is that under these circumstances, lobectomy has given satisfactory results when

TABLE III. RESULTS IN 31 PNEUMONECTOMIES FOR PULMONARY TUBERCULOSIS

		TOTAL	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939
Endobronchial tuberculosis	Not followed	1		1								
	Clinically well	6	2	1	1		1[A]			1		
	Alive with active disease	0										
	Died	2									1	1
Extensive unilateral disease	Clinically well	6	4	1	1							
	Alive with active disease	1	1									
	Died	4	4									
Thoracoplasty failures	Clinically well	2	1				1[B]					
	Died	1										1
Diagnosed tumor preoperatively	Clinically well	3	1	1			1					
	Died	1		1								
Suppurative disease eroding tuberculous focus	Alive with active disease	1	1									
	Died	1					1					
Schede failure	Clinically well	1	1									
Lobectomy for bronchiectasis in 1944. tbc in remaining lobe.	Clinically well	1		1								

[A] Questionable activity that cleared in remaining lung.

[B] Thin walled cavity with negative sputum that cleared rapidly—? Emphysematous bleb.

TABLE IV. CAUSE OF DEATH IN 9 PATIENTS AFTER PNEUMONECTOMY FOR TUBERCULOSIS

DATE OF PNEUMONECTOMY	TIME OF DEATH	COMMENT	CAUSE OF DEATH
1939	48 days	Severe tuberculous bronchiectasis with suppuration and positive sputum. Only procedure was ligation of one vessel. Operation abandoned, because of uncontrolled secretions. Developed massive spread	Massive spread
1939	2 days	Patient poor functional risk. Lobectomy planned, pneumonectomy necessary. Very stormy postoperative course with marked respiratory difficulty and bronchiogenic spread to opposite side	Respiratory failure and spread
1940	6 days	Long history of tuberculosis, empyema, BPF, drainage, and complete thoracoplasty. Pneumonectomy followed by massive spread	Massive spread
1944	6 days	Quiescent Friedlander pneumonia, bronchiectasis, and fibrocaseous tuberculosis preoperative. Postoperative massive Friedlander's spread with fibrocaseous tuberculosis in other lung.	Massive Friedlanders and tuberculosis
1947	10 days	Diagnosed as Ca. preoperatively. Fibrocaseous tuberculosis in lung. Bronchopleural fistula, empyema, and massive spread	Massive spread with Bronchopleural fistula
1948	1 month	Borderline functional risk. Lobectomy planned, pneumonectomy done because of technical difficulties. Survived stormy postoperative course, then did well. Died 2 days after thoracoplasty of respiratory failure	Respiratory failure
1948	5 days	Patient had extensive unilateral disease and laryngotracheal disease controlled with streptomycin. Postoperative tracheotomy necessary. Died suddenly from apparent blockage of airway. Section from trachea showed acute edematous swelling and acellular membrane formation	Asphyxia after tracheotomy
1948	2 days	Extensive unilateral tuberculosis. Uneventful pneumonectomy. Developed pulmonary edema with high Hct and Hgb, probably result of overtransfusion.	Pulmonary edema
1948	3 weeks	Extensive disease. Period of cardiac arrest at operation. Followed by marked evidence of cerebral damage. Never recovered consciousness. No tuberculosis found in opposite lung	Cerebral anoxia with extensive brain damage

each patient is considered individually. The group of patients who had pneumonectomy reflect a more extensive disease by a higher mortality. In reviewing these cases, it was difficult to visualize any other form of therapy that would adequately have controlled the disease. When the indication was extensive unilateral disease, it was noted in the pathology report that caseation was present in many areas. In reviewing the group that is listed as thoracoplasty failures, it is brought out that most of these result from caseous disease which continues to excavate in the area under collapse. Initial resection offers a much more favorable outlook in such lesions.

After pneumonectomy, thoracoplasty has been done routinely leaving the first rib in place and with limited resection of the posterior segments. Scoliosis is seen infrequently after this procedure.

These patients were all seen in a general hospital where pulmonary suppuration is not an uncommon disease. Several patients included in this report were operated upon with this diagnosis. In a few of these the process was tuberculous and was undiagnosed. We now have had a considerable experience with acute lung abscess which occurs in an area adjacent to quiescent tuberculosis and as the process extends and invades the tuberculous area, the sputum becomes positive and the copious secretions form an excellent vehicle for spread. The combination of suppurative disease and tuberculosis in the same lobe is a strong indication for resection.

SUMMARY

1. Seventy-three cases of pulmonary resection for tuberculosis in the period 1939 to October, 1948, are presented.

2. Lobectomy combined with thoracoplasty and streptomycin gave the most satisfactory follow-up results.

3. The indications for lobectomy were discussed. Poor results in the late follow-up period need not be anticipated. There remains a group in whom thoracoplasty or lobectomy offers a considerable chance for improvement. The choice of procedure must be individualized.

4. Pneumonectomy usually was undertaken for far-advanced lesions and the high mortality is not a contraindication for its continued use.

CONCLUSION

In conclusion, it seems evident that there are many patients in whom thoracoplasty and resection may be anticipated to offer the best opportunity for control of the disease.

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DISCUSSION ON "FURTHER EXPERIENCES WITH SEGMENTAL RESECTION IN TUBERCULOSIS" BY DR. J. MAXWELL CHAMBERLAIN AND DR. ROBERT KLOPSTOCK;* "RESECTION IN THE TREATMENT OF PULMONARY TUBERCULOSIS" BY DR. J. CLAUDE DAY, DR. W. M. TUTTLE, DR. E. J. O'BRIEN, DR. FOSTER HAMPTOM, JR., AND DR. TRUXTON L. JACKSON,† AND "LOBECTOMY AND PNEUMONECTOMY IN THE TREATMENT OF PULMONARY TUBERCULOSIS" BY DR. AARON HIMMELSTEIN, DR. FRANK B. BERRY, AND DR. C. THOMAS READ

COL. JAMES H. FORSEE, Denver.—Prior to 1947, it was our belief that pulmonary resection in tuberculosis was seldom indicated except for thoracoplasty failures and in certain instances of bronchial stenosis. Beginning in 1947, and with the advent of adequate quantities of streptomycin, we have carried out lobectomy in a consecutive series of 94 patients, with a mortality rate of 2.1 per cent. Reactivation or spread of the disease has occurred in five patients, bronchopleural fistula in five, and empyema in three patients. In an over-all summary of 124 patients treated during the period 1947 through 1949, on whom pulmonary resection was performed as pneumonectomy, lobectomy, segmental or partial lobectomy, the over-all mortality to date is 4 per cent.

We believe it important to carry out upper stage thoracoplasty of five ribs, either preceding or at the same time lobectomy is performed. Of extreme importance and only to emphasize its significance, is the importance of teamwork in caring for such patients, including the internist, endoscopist, and pathologist. Our most important recent contribution has been the work carried on by Colonel Temple and his co-workers at Fitzsimons in a study of streptomycin resistance. Briefly, in a group of 100 patients who have been treated with streptomycin for a period of 120 days, in dosages of 1 or 2 Gm. every third day, combined with para-aminosalicylic acid 12 Gm. daily, one-third have completed the study and have had resistance studies made. To date, there has been no instance in which sensitivity has not been retained in the 33 patients. The other 67 have completed their course of streptomycin and PAS therapy, but resistance studies are not complete. This is particularly important to the surgeon in that if the patient who undergoes pulmonary resection is sensitive to streptomycin he is a better risk and has a better chance for ultimate recovery. The one common denominator since 1947 which has made pulmonary resection such an adequate measure in the management of pulmonary tuberculosis is, in our minds, streptomycin.

DR. ANTHONY R. CURRERI, Madison, Wis.—While in the main I believe we agree with the philosophy of Dr. Chamberlain, I think many of us might take exception to one point that he has made; that is, that one can tell by x-ray examination all of the active tuberculosis present in the lung. This is not true, because in our series, by correlating roentgenograms and planograms to the surgical and pathologic findings, we noted that many lesions not seen in the x-ray examination became apparent on surgical exploration, and active infection was demonstrated by lung sectioning and microscopic and bacteriologic studies.

Furthermore, in our first series of 80 cases, segmental resection was carried out in 4 cases, two of these developing bronchopleural fistula and a third had excessive pleural effusion. We decided, therefore, that segmental resection should be resorted to when mandatory be-

*See page 843 for article by Chamberlain and Klopstock.
†See page 854 for article by Day, Tuttle, O'Brien, Hampton, and Jackson.

cause of inadequate pulmonary reserve. Our results are in complete agreement with Dr. Berry's and Dr. Himmelstein's. We wish to compliment Dr. Day and his co-workers in focusing our attention on the possibility of major complications, particularly bronchopleural fistula that may be associated with resection. However, we are convinced from our own studies, in which some cases have now gone over five years, that in properly selected cases pulmonary resection has a definite place in surgical treatment of tuberculosis, should be attended with excellent results and few complications.

In April, 1948, Dr. Gale and I reported 80 consecutive resections for tuberculosis. We have continued to follow these cases closely, and in addition have performed another 120 resections up to November, 1949. May I show three slides demonstrating the results of these cases?

(Slide.) You will note that in our original report of April, 1948, 42 per cent of the patients were sputum negative but still in a sanatorium, 31 per cent were negative and at home, and 22 per cent were positive. By September, 1949, one and one-half years later, there were but 12 per cent that were sputum negative and still in a sanatorium, while another 63 per cent were negative and at home—indicating that 75 per cent had converted and the vast majority were at home. Fifteen per cent of the patients were still positive. Our original 1948 series showed two deaths attributable to the operative procedure. Three more died from unrelated causes. In the ensuing two years two more patients have died from causes other than tuberculosis, making a total of seven deaths from the original series of 80.

(Slide.) This shows the stability of sputum conversion. Note that in the original report sputum conversions were under eighteen months, while eighteen months later the vast majority of patients have been tubercle free for well above twenty-four months, with a fair number free of tubercle bacilli for four to five years.

The third slide presents our surgical indications and the mortality of the original group as compared to the second group of 120 resections performed between April, 1948 and November, 1949. Whereas thoracoplasty failure and bronchial stenosis accounted for approximately three-fourths of our indications in the first group, in the second group the picture changed, with bronchiectasis the indication in 35 per cent, thoracoplasty failure in 27 per cent, and bronchial stenosis in 6 per cent. There were five operative deaths in the second series, about double the original group. This increased mortality is partly our fault, for with increasing success we accepted patients with extensive bilateral disease or those resistant to streptomycin and still having evident tracheobronchitis. Further, streptomycin deceived us in several cases for, despite the apparent subsidence of bronchitis as manifested by a healing mucosa, section of the bronchus at the time of surgery revealed a cheesy submucosa. Obviously the selection of such cases resulted in a high incidence of respiratory cripples and bronchopleural fistulas. There were three respiratory cripples, one of whom died, and nine bronchopleural fistulas. A lesson was learned from the bronchopleural fistulas in that we attempted to close the blown bronchial stump in five cases, and four of these died. The remaining four had immediate drainage performed, followed by thoracoplasty. Three of these have spontaneously closed their fistulas.

DR. JOSEPH GORDON, Ray Brook, N. Y.—I should like to bring to you some information that has been helpful to us, which does not include a series of cases. At Ray Brook we have continued with our studies of the removed lung specimens by injecting the pulmonary artery and the bronchial tree and carefully studying these specimens for the extent, distribution, and type of pathologic change which is present. With these studies as the base line we feel that we have a better method of evaluating bronchography. We believe bronchography has reached the point where it is extremely helpful in eliciting the structural changes present in the lung before embarking upon surgical planning of these cases.

(Slide.) Here you see on the left the x-ray film of a markedly destroyed lung on which pneumonectomy was done. The film following it is that of an arteriogram of the pulmonary artery showing marked destructive changes in this area. The film following that is the bronchial tree injected, showing the alteration in the bronchial tree. These, as we mentioned

last year, show changes both in the pulmonary artery and in the bronchial tree in tuberculosis. It is these changes that correlate so well with the distribution of disease that we have used them as a basis for bronchographic interpretations.

(Slide.) Here you see what looks like a moderately diseased lung on the left side, but the bronchogram shows an extremely poor pattern and this is a relatively nonfunctioning lung. The bronchial pattern reveals areas of extensive structural changes by absence of arborization with shortening and widening of the bronchial tree.

(Slide.) Here is an x-ray film which shows moderate disease, the location of which is not accurately indicated except that we see it is rather extensive. The bronchogram on the right shows that the upper lobe is involved as well as the apical segment of the lower lobe. The remaining portion of the lung has a relatively normal bronchial tree and we therefore feel that the attack on this should be localized to the areas of abnormal bronchograms.

(Slide.) This is the post re-expansion bronchogram in a case in which there is no function in the lung. The bronchial tree shows the same marked alteration, absence of arborization, shortening and widening.

(Slide.) The x-ray film shows disease on the left in the region of the upper lobe and a portion of the lower lobe; the bronchogram shows that the disease in the upper lobe is rather widespread and only the apical portion of the lower lobe is involved; the remaining portion of the bronchial tree is normal, so we could confine resection to the upper lobe and apical portion of the lower lobe.

(Slide.) This is a similar case; the same abnormal changes in the bronchial tree.

(Slide.) This case shows the contrast; there is a giant-sized cavity in the apex of the lower lobe; the bronchogram, however, is abnormal throughout, and it would be inadvisable to attempt a segmental or lobe resection, because the entire lung is involved and must be so treated.

(Slide.) This shows abnormal changes in bronchogram in the presence of involved lung.

(Slide.) This is the most striking case of all, of a patient who had minimal disease in March, 1949, then developed pneumonic type of disease in July, 1949, of the right upper lobe, for which the patient was treated with streptomycin. There is marked regression of the abnormal shadows. The interpretation is extensive clearing. However, the bronchogram shows rather extensive alteration of all segments of the upper lobe.

DR. ROBERT GLOVER, Philadelphia.—I should like to congratulate the essayists on their very excellent presentations and results, and particularly Dr. Chamberlain for undertaking this interesting and important work, for the courage it took and also his excellent results.

(Slide.) Two years ago we were privileged to present before this Association a series of 200 consecutive cases of resections for pulmonary tuberculosis. This series started in 1941, and terminated early in 1948. The slide presents an initial series of 100 cases with a mortality rate of 27 per cent; those cases did not have the benefit of streptomycin. The next 100 cases had the benefit of streptomycin and the mortality rate was reduced to 16 per cent.

(Slide.) We have extended this series to include 347 cases to the first of this year. There have been 58 deaths in the entire series, which represents an over-all mortality of 16 per cent. There have been an additional 20 deaths in the postoperative period to date, bringing the entire mortality up to 22 per cent. Living at the present time are 269 cases. Within the past three months we have endeavored to carry out a very extensive follow-up and have been able to contact each patient. We find that of the original 347 cases, at the present time there are 242 negatives, representing approximately 70 per cent of the entire series. There are 27 positive cases, or 7.7 per cent.

DR. WILLIAM M. TUTTLE, Detroit.—It seems rather interesting that Dr. Chamberlain has been able to gather together such a large group of segmental resections in the treatment of tuberculosis. This is especially so in view of the fact that there have been relatively few segmental resections done in a combined series of almost 800 resections reported here today. While Dr. Chamberlain did not have an opportunity to demonstrate by lantern

slide the type of lesion to which he applies segmental resectional surgery, one is forced to assume that in some instances these patients might have been adequately treated by simpler collapse measures.

In reference to our own series and to the others reported here today it becomes evident that we have, I believe, not taken into consideration to a sufficient degree why patients after resectional surgery die either early or late. In our group it is quite evident that the majority of our deaths occurred as a result of the opening either early or late of the bronchial stump. It is likewise interesting that the majority of these stump openings occurred on the right side where the stump is more difficult to bury. This, I believe, fits in well with the observations of Dr. Rienhoff, which were made many years ago, namely, that a well-buried bronchial stump in the experimental animal seldom opens. The various series reported here today would remind us again that adequate bronchial closure still presents a problem.

DR. LOUIS R. DAVIDSON, New York.—I should like to echo Dr. Glover's complimentary remarks relative to the essayists. The very interesting paper of Dr. Day I agree with almost completely, but I should like to take this particular exception. If there ever was an indication for excisional surgery it is in the destroyed lung. Perhaps I did not hear Dr. Day correctly, but I feel that that is, beyond the shadow of doubt, one of the most important indications for excisional surgery.

Between March, 1946 and December, 1948, at Seaview Hospital, 200 resections for pulmonary tuberculosis were performed by 15 operators. Most of the surgery was done by the resident staff. There were 157 pneumonectomies, 38 lobectomies on 32 patients, and 13 segmental resections on 11 patients. During 1949, these cases were screened and classified rather intensively by reviewing the history, laboratory findings, x-ray studies, surgery, and pathologic material. In addition, most of the cases were seen in the follow-up clinic. One hundred ninety-two of the 200 specimens were evaluated; in a certain few instances we were of the opinion that excessive tissue had been removed when pneumonectomy was performed. Among our conclusions, it was believed that most pressing needful conditions demanding excisional surgery, were previous surgical failure, mixed infections, tuberculous empyema bronchopleural fistula, and a destroyed lung. Our ideas concerning the status of the contralateral lung or the remaining ipsolateral lung, and their relationship to surgery, have been altered during these years, particularly because of our study of these pathologic specimens. We like to call the arrested type the encapsulated caseous foci, and we think the contralateral lungs as shown in the films play no part in the consideration for surgery, if there is a stable lesion that has been present for a substantial period of time.

(Slides.) This patient was operated upon about 25 months ago; a pneumonectomy was performed. (Slide.) This shows the condition in January of this year; he is in good health and doing very light work.

Of Total 200 Patients

151 alive and sputum negative	75.5%
9 alive and sputum positive	4.5%
40 deaths	20.0%
29 bronchopleural fistulas	14.5%
6 empyemata	3.0%
17 sinuses and wound breakdown	8.5%
7 tuberculosis spreads	3.5%

DR. JULIAN A. MOORE, Asheville, N. C.—I should like to congratulate Dr. Chamberlain on his excellent results, but I cannot agree that segmental resection has as yet replaced thoracoplasty. I think after a period of five years if the results remain good it may prove his point. We have done only a few segmental resections without any mortality rate; have had two spreads of the disease at a later period following segmental resection. We have now done at Oteen more than 200 resections, and we have more complications. The trouble comes from two sources. We are beginning to get late fistulas, late empyemas, late spreads. So we

do not know what the final result will be. However, the complication rate is greater in those patients who have been treated with streptomycin before they came to surgery. We are getting very few patients who have not received streptomycin, and the complication rate has doubled.

Where we are able to control the administration of streptomycin a little better our complication rate remains low. I am rather appalled in private practice at seeing so few patients with tuberculosis who have not been given streptomycin at the beginning of the disease. At this rate, five years from now, the tuberculous population of this country will be streptomycin-resistant. I feel that its use should be confined to definite indications and that it should not be given indiscriminately. I am also certain that streptomycin is still a protective agent and an adjunct particularly to resection and major collapse measures.

DR. JOHN JONES, Los Angeles.—I thought it might be of some interest to you to see a recent study we have made of our cases, Dr. Robinson, my associate, and I. We have used essentially the same technique on these patients on the group operated upon between 1943 and 1949. In all, we had a mortality of 12.2 per cent in 123 resections; and in the group classified as collapse failure, we have 24 per cent mortality; in the destroyed lung group we had 40 per cent mortality; and in that smaller group of 32 patients where the operation was purely elective we had no mortality and a fairly low incidence of complications.

(Slide.) What are the causes of these complications and the mortality? We found in the entire group that our greatest problem was spread of the disease, which accounted for 90 per cent morbidity, 5.7 per cent mortality; opening of the stump, 2.4 per cent mortality. The other causes were 1 per cent wound infection; two operative deaths, 1.6 per cent mortality.

(Slide.) If we compare the group operated on before we had streptomycin with those that had the advantage of streptomycin, we have the complication of empyema, for example. In the 35 patients who had no streptomycin, the mortality from empyema was 2.8 per cent, and an incidence of 11.4 per cent in the group of 35 patients. Still, in the group of 88 patients who had streptomycin, we had only 2.3 per cent morbidity, and no mortality from that one complication.

(Slide.) The opening of the bronchial stump was of course a common cause of mortality—8.6 per cent in a group of 35 nonstreptomycin patients, and still we had no bronchial fistulas in the 88 who had streptomycin.

(Slide.) The third complication was spread of the disease. We had 17 per cent of our patients die of spread of the disease in the small group of 35 nonstreptomycin patients, and still only 1.1 per cent in the 88 patients who had streptomycin. The technique was essentially the same; there were only two surgeons who operated upon these patients. All the bronchial stumps were closed with stainless steel sutures. We have here a total mortality of 5.7 per cent due to opening of the stump, all in the nonstreptomycin group.

(Slide.) Finally, if you group all the figures together, you will not have such a good mortality, 12.2 per cent; but if you look at the patients who had streptomycin you have a fairly respectable mortality of 5.7 per cent in 88 resections, but still an appalling mortality of 25 per cent in the 35 patients who did not have streptomycin, and more than 50 per cent morbidity in that small group. In reporting statistics on resections in tuberculosis it is, then, obvious that it is well to state whether the patients had the protection of streptomycin during their surgical treatment.

DR. CLARENCE CRAFOORD, Stockholm, Sweden.—There is no doubt that the incidence of bronchial fistula has been on the decrease since we have had chemotherapy, both in tuberculosis and in nontuberculous cases. I believe that safe bronchial closure is not only due to chemotherapy, it is also due to the technique with which the bronchial stump is closed. If there is not any naked cartilage left in the stump to be closed, and if the closure can be done with a continuous peripheral suture and invagination, the incidence of bronchial fistula will be very small, both with and without chemotherapy. In our early experience, resections

both in tuberculous and nontuberculous cases, gave a very small incidence of bronchial fistula, and since 1945, when we got chemotherapy, I cannot remember any cases of bronchial fistula in my material.

With regard to the cases presented by Dr. Chamberlain and discussed by Dr. Tuttle, I believe that the type of tuberculosis we have in Sweden is quite different from the type you have in the United States. If we tried to close any of the cavities which Dr. Chamberlain has resected with phrenic nerve operation, as Dr. Tuttle advised, I do not believe we would get success in more than perhaps 1 or 2 per cent.

DR. NORMAN WILSON, Boston.—I also would like to congratulate the three essayists, and I think it is well for us to remind ourselves as we look at the statistics of the last two papers, that had they chosen to break them down into recent years, in the streptomycin era, their over-all figures wound have been much better, I rise merely to give you a late follow-up of a series of cases, and also what we consider to be the results in the modern era with everything we have to use.

In June of last year we were able to follow 100 per cent of living patients of the first 323 resections. Of this group 75 per cent were living; 80 per cent were classified by their own physicians as well in May. Sixty-six per cent of these patients were followed more than three years. The interesting point to us was, that of all the people who died of tuberculous infection, all save 10 had died of a progressive postoperative complication, or a complication related to a postoperative complication—in other words, fistula and spread. Only 10 people had died of an old progressive lesion, which would indicate that if we can carry these people through the operative period safely, their prognosis should be good.

In the last three years, with streptomycin and, I believe also, with more intelligent selection of patients, and, contrary to Dr. Tuttle's conception, with an increased application of segmental resection, I think we have been able to do a better job in many cases. In that period we have done 209 cases, 137 pneumonectomies, 48 lobectomies, and 24 segmentals. In the pneumonectomies, the tuberculous complications total has been 7 per cent; lobectomies, 2 per cent; segmentals, 4 per cent. Tuberculous deaths in pneumonectomies, 0.7 per cent; lobectomies, 0 per cent; segmentals, 0 per cent. The total tuberculous deaths, 0.5 per cent.

The nontuberculous deaths are increasing because our age groups are getting older. We have eight patients with pneumonectomies dead from a nontuberculous cause such as shock or coronary occlusion; we have 2 per cent lobectomy patients dead from nontuberculous causes; we have one segmental, who died of an embolus. I think these results should encourage Dr. Chamberlain to continue.

DR. CHAMBERLAIN (Closing).—First, may I make a correction; in the slide in which I showed the complications, I said there were three reactivations—there were actually five. These five are described in the manuscript. I did not mean to deceive you. Each reactivation and each death is explained in the text.

I should like to thank all the discussors for both their constructive and destructive criticism. Dr. Curreri spoke of the activity of foci; I thought I had pointed out in the text that there were three types of lesions left behind: (1) active ones, which I believe we all recognize from changes in the serial x-rays; (2) the indolent ones, in which the x-ray changes are so slight we cannot tell much about them; and (3) the arrested ones. It was also mentioned that all residual foci were treated as though they were indolent or smoldering foci, and therefore the patients were given six months bed rest after the resection. Dr. Curreri also suggested that the operation should be used only in patients with low respiratory reserve. From our present experience, the patient with a low respiratory reserve is not the type of case on which segmental resection should be tried. Segmental resection will rarely pull a bad risk patient out of a precarious functional situation; on the contrary, one slight complication, after segmental resection or any other procedure, may put the patient with a low respiratory reserve beyond the margin of safety. Our unfortunate results have been in patients who were considered poor risk patients for all other procedures as well. I don't know how to explain his three out of four failures in segmental resection. However, in the

six bronchial fistulas which we have reported, three occurred almost consecutively; I am sure, had they been my first three cases I would feel as Dr. Curreri does. I can only say that he should give the procedure another trial, and perhaps his results will not be so unfortunate.

Dr. Tuttle surprised me by his discussion because I took this paper to Detroit and tried it out about nine months ago at the meeting of the National Tuberculosis Association. I believe Dr. Tuttle was in the audience when we showed the first 15 or 16 consecutive cases that we had done. At that meeting he held his tongue and so I thought I was safe in presenting it here today. He referred to the deaths. I think it was pointed out that the anesthetic death was the one case directly related to the operation and, under normal circumstances would have been considered a surgical death. The accident was simply this: At the end of the operation and after the patient was dressed and turned on his back, the anesthetist turned on the oxygen tank. The intratracheal tube was still in place and its balloon inflated. For some reason the reducing valve did not work and the patient received the entire pressure of the oxygen tank and blew up on the table. Death was immediate. Since we did not have an opportunity to find out whether he was or was not going to die from the operation, several of us felt that perhaps it was fair to call this an anesthetic death.

Dr. Tuttle pointed out also that in their 200 cases they have done no segmental resections; that the Madison group have done no segmental resections; and that in many other reports they have done no segmental resections. My only response to this observation is that in 1930 no one had done any resections.

Dr. Julian Moore made perhaps one of the most valuable comments. In my notes, which I did not have time to read, the last sentence states—"This operation is not a panacea, nor is it done without hazard, and it will require at least five years for real evaluation."

DR. DAY (closing).—I should like to thank all the discussors. Dr. Wilson has been so kind as to point out that we made no effort to separate the recent results from those of earlier years. Our recent results, of course, show lower fatality and morbidity rates than those for the total series.

I should like to thank Dr. Davidson for his kind remarks. We have been deeply concerned about the problem of the open bronchus. It is somewhat reassuring to know that we are not the only ones plagued by this problem. With regard to the destroyed lung, I think we are not particularly at variance with the opinion of Dr. Davidson and others. A large number of lungs which, perhaps, one would classify as destroyed were found to have high grade stenosis of the stem bronchus and were, therefore, included in the bronchostenosis group.

I should like to correct the impression that we have not done any segmental resections. Separate mention will be made of them in the manuscript. Though accompanied by more difficulties than the lobectomies, the results have not been too bad. I believe that Dr. Tuttle's criticism of Dr. Chamberlain is rather more severe than intended. I think Dr. Chamberlain is to be congratulated for his courageous attack on this problem. I am sure that Dr. Tuttle believes with the rest of us that segmenal resection will, indeed, play an increasingly important part in the treatment of pulmonary tuberculosis.

DR. HIMMELSTEIN (closing).—I would like to emphasize that our report includes cases operated on prior to the end of 1948, so that our shortest follow-up is about a year and one-half. The comments by Dr. Wilson hold for the cases we have seen; there has been one death in the lobectomy group since the use of streptomycin.

PULMONARY RESECTION IN TUBERCULOSIS: ITS HAZARDS, INDICATIONS, AND RESULTS

JOHN C. JONES, M.D., AND JOSEPH L. ROBINSON, M.D.
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THE extent to which any therapeutic procedure is used in the treatment of pulmonary tuberculosis is constantly modified by the results obtained. This is especially true in the early years of the development of a new surgical measure. Time and experience are required for the perfection of the technique and for the recognition and modification of the characteristic hazards. Even more time must elapse during which large numbers of patients are followed and compared with patients on whom more familiar therapeutic procedures have been performed. At the present time, the surgical technique of pulmonary resection has been fairly well developed and standardized, but the observation of the results obtained through its use is still in its early phase. Until comparatively recently, indications for resections were based largely upon medical necessity. Patients came to the thoracic surgeon for resection because there simply was nothing else available for them. Any extensive use of the operation as an elective procedure was limited by the high morbidity and mortality rates which accompanied it. Table I contains statistics collected from the literature, reporting operations done previous to 1947 from three large surgical clinics. In a total of 343 operations, the morbidity rate was 51 per cent, the mortality rate 28 per cent.

TABLE I. COLLECTED STATISTICS

SURGEON	NUMBER OF PATIENTS	MORBIDITY		MORTALITY	
		NUMBER	PER CENT	NUMBER	PER CENT
Overholt[1]	200	82	41	51	25
Bailey[2]	80	56	70	23	27.5
Sweet[3]	63	36	57	21	33
Totals	343	174	51	95	28

Our experience previous to 1947 was quite similar. We had done 27 resections with a morbidity rate of 37 per cent and a mortality rate of 29 per cent.

THE HAZARDS OF PULMONARY RESECTION IN TUBERCULOSIS

The high morbidity and mortality rates previously described were not due to any fault in surgical technique, since the immediate operative mortality was extremely low, but were rather due to factors inherent in the disease itself. Since 1947, we have performed 96 resections on 95 patients, making a total of

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123 operations in 122 patients in the six-year period. The causes for the complications and deaths were not long in being recognized, and fall into three categories:

1. Progression of pulmonary disease
   A. Early bronchopneumonia, either tuberculous, nontuberculous, or mixed.
   B. Late. Evolution of latent or new foci of disease in the lung.
2. Opening of the bronchial stump
   A. Early, due to failure to heal.
   B. Late, due to progressive ulceration and sloughing.
3. Empyema
   A. Early, due to overwhelming contamination at surgery.
   B. Late, due to progression of pleural tuberculosis.

TABLE II. HAZARDS OF PULMONARY RESECTION FOR TUBERCULOSIS

PRIMARY COMPLICATIONS	TOTAL, 123 OPERATIONS				35 OPERATIONS NO STREPTOMYCIN*				88 OPERATIONS STREPTOMYCIN			
	MORBIDITY		MORTALITY		MORBIDITY		MORTALITY		MORBIDITY		MORTALITY	
	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT	NUMBER	PER CENT
Spread of Disease	11	9.0	7	5.7	7	20.0	6	17.1	4	4.5	1	1.1
Early	9		7		7		6		2		1	
Late	2		0		0		0		2		0	
Opening of Bronchial Stump	5	4.0	3	2.4	5	14.1	3	8.6	0		0	
Early	1		1		1		1		0		0	
Late	4		2		4		2		0		0	
Empyema	6	4.9	1	0.8	4	11.4	1	2.8	2	2.3	0	
Early	1		1		1		1		0		0	
Late	5		0		3		0		2		0	
Wound Infection	1	0.8	0		1	2.9	0		0		0	
Operative	2	1.6	2	1.6	0		0		2	2.3	2	2.3
Unknown	2	1.6	2	1.6	0		0		2	2.3	2	2.3
Total	27	22.0	15	12.2	17	51.5	10	28 6	10	11.4	5	5.7

*Included are 8 patients whose organisms had become streptomycin resistant due to long-continued heavy doses. All had serious complications.

In studying the complications which occurred in our patients, we have placed in one group those who did not receive streptomycin, or whose bacilli had become resistant to it through long continued large dosage; and in a second group all those patients who received effective streptomycin therapy.

A spread of their disease occurred in 7, or 20 per cent, of the 35 no-streptomycin patients, with a mortality of 6, or 17.1 per cent. This complication occurred in 4.5 per cent of the 88 patients who received streptomycin with a mortality of only 1, or 1.1 per cent.

Opening of the bronchial stump occurred in 5, or 14.1 per cent of the no-streptomycin group, with a mortality of 3, or 8.6 per cent. In the streptomycin group this complication did not occur.

Empyema was a complication in 4, or 11.4 per cent of the no-streptomycin patients with a mortality of 1, or 2.8 per cent. It occurred in only 2, or 2.3 per cent of the patients receiving streptomycin, with no deaths.

There was one tuberculous wound infection in a no-streptomycin patient, and none among the streptomycin patient group.

Two deaths are listed as operative. One of these patients died on the operating table from an unfortunate anesthetic complication. During the middle portion of the operation, his color was not good, and the anesthetist could do nothing to improve it. However, in transecting the bronchus of the diseased lung, the intratracheal tube was seen to be protruding into that bronchus. He died just before completion of the surgery, of anoxia. The other patient was a known asthmatic. She appeared to have an uncontrollable bronchospasm following surgery, and failed to respond to antishock therapy. Blood pressure remained under 90 until her death, some fifteen hours after completion of the surgery.

Two deaths have not been explained. One occurred suddenly on the third postoperative day. The other patient did well until the fifth postoperative day and then became increasingly dyspneic until her death thirty-six hours later. In neither case was an autopsy obtained, and in neither case did x-ray examination reveal evidence of contralateral disease, or of other cause for death.

Before the advent of streptomycin, every effort was made to find means for preventing the development of these dreaded complications. Patients who had much bronchial secretion were operated upon in the deep Trendelenburg, or the face-down Overholt, position in order to keep the secretions out of the bronchial tree as much as possible. In addition, anesthetists were asked to make every effort to keep the trachea and bronchi aspirated continuously during the time of the operation. In the postoperative period, meticulous care was exercised over the patient's bronchial toilet. Frequent change in position, liberal use of carbon dioxide inhalations, and tracheal and bronchial aspirations by catheter were all a matter of routine use. Postoperative thoracoplasties were used more extensively in an effort to prevent any undue strain upon the remaining lung tissue and thereby reduce the likelihood of reactivating latent disease. But in our opinion, the greatest aid to the elimination of postoperative morbidity came with the advent of streptomycin. Other surgeons[4, 5] have reported similar improvements in postoperative results since streptomycin has been available for their patients. We believe that the decision to use streptomycin on any given patient with tuberculosis should not be taken lightly, especially if there is any likelihood that he may require surgical collapse or extirpation of diseased lung tissue later on. If streptomycin is given, every effort should be made to prevent the development of streptomycin resistance by the use of techniques and/or other antibiotic agents which reduce the development of resistance in tubercle bacilli.

INDICATIONS FOR RESECTION

We have studied our patients in relation to the primary indication for which resection was performed. In some instances, there was more than one

indication, but we have tried to classify them according to the indication of primary importance. As in the study of the complications, we have again grouped them according to whether or not they were able to have effective streptomycin therapy. Table III classifies them according to age and sex.

TABLE III. AGE AND SEX

	10-19 YEARS	20-29 YEARS	30-39 YEARS	40-49 YEARS	50-59 YEARS	TOTAL
Male	0	4	12	11	1	28
Female	2	23	29	28	12	94
Total	2	27	41	39	13	122

It was seen that there is a remarkably high preponderance of women, some 77 per cent. The ages range from 19 to 58 years.

1. Collapse failure. Of the 25 patients in this group, 17 had had a thoracoplasty, and 8 had had either pneumothorax or pneumoperitoneum and had residual cavities so located as to make them unlikely candidates for successful thoracoplasty. Those patients with disease which might respond to thoracoplasty but in whom the decision to do a resection was eventually made, are included in the elective group. As will be seen in Table IV, the mortality rate among the no-streptomycin group was 40 per cent compared to 13.3 per cent for those receiving streptomycin.

2. Destroyed lung. The requirement for this indication was such extensive basal, as well as apical, disease as to make a successful thoracoplasty most unlikely. Disease largely limited to one lobe with a so-called giant cavity has not been included in this category. The decision as to whether to do a thoracoplasty or lobectomy for large upper lobe cavities has been determined by other considerations. The true tension cavity, which consists of a relatively small area of pulmonary ulceration blown up to a large diameter by a check-valve mechanism in its draining bronchus, will frequently respond very well to a course of streptomycin or similar antibacterial drugs, followed by a thoracoplasty. Experience in the use of Monaldi cavity drainage, which one of us (J. L. R.) had years ago, demonstrated that the thick wall of a true tension cavity is usually merely a rim of atelectatic lung which will disappear as the mechanism within the draining bronchus which has produced the tension cavity is overcome. It is therefore essential to make a careful study of the antecedent roentgenograms in a given case before deciding upon thoracoplasty or resection. With a few difficult problems, we have found it useful to give a short course of one of the antibacterial drugs, followed by a first stage thoracoplasty. If the cavity reduces in size and loses its balloon shape, the thoracoplasty may then be continued. If not, a resection should be done.

3. Chronic bronchial disease. In this category fall those patients with bronchial stenosis, bronchiectasis, or chronic pulmonary suppuration. The disease must have been demonstrable by bronchoscopy, bronchogram, or body section x-ray examination. Patients in whom bronchiectasis or bronchostenosis

TABLE IV. INDICATIONS FOR RESECTION IN TUBERCULOSIS

PRIMARY INDICATION	TOTAL: 123 OPERATIONS			NO STREPTOMYCIN: 35			STREPTOMYCIN: 88		
	NUMBER	MORBIDITY	MORTALITY	NUMBER	MORBIDITY	MORTALITY	NUMBER	MORBIDITY	MORTALITY
1. Collapse failure	25 = 20.3%	7 = 28. %	6 = 24. %	10 = 28. %	5 = 50. %	4 = 40. %	15 = 17. %	2 = 13.2%	2 = 13.2%
2. Destroyed lung	10 = 8.1%	6 = 60. %	4 = 40. %	6 = 17.7%	4 = 67. %	3 = 50. %	4 = 4.5%	2 = 50. %	1 = 25. %
3. Chronic bronchial disease	51 = 41.5%	8 = 15.7%	5 = 9.8%	13 = 37. %	6 = 46. %	3 = 23. %	38 = 43. %	2 = 5.3%	2 = 5.3%
4. Diagnostic	5 = 4. %	0	0	1 = 3.2%	0	0	4 = 4.5%	0	0
5. Elective	32 = 26. %	6 = 18.7%	0	5 = 14.2%	2 = 40. %	0	27 = 31. %	4 = 14.8%	0
Total	123 = 100%	27 = 22. %	15 = 12.2%	35 = 100%	17 = 51.5%	10 = 28.6%	88 = 100%	10 = 11.4%	5 = 5.7%

of the smaller bronchi was suspected but not proved, are not included in this group, but comprise a rather large segment of the elective group—especially among the patients receiving lobectomy. It is in this third group that streptomycin has been most helpful in preventing complications and death. As will be seen in Table IV, the mortality rate among the patients in this group not receiving streptomycin was 23 per cent, whereas among the patients receiving streptomycin, it was only 5.3 per cent. Actually there were no tuberculous complications from it, the two deaths which did occur being operative deaths—one due to an unfortunate anesthetic complication, and the other due to unmanageable postoperative shock.

4. Diagnostic problems. Occasionally it is unwise to delay surgery while a time-consuming search is made by culture or animal inoculation for tubercle bacilli. This is especially true in the older age group of patients where bronchiogenic carcinoma may be suspected. It has been our policy to explore these patients, and if the diagnosis cannot be made by gross examination alone, or of an available lymph node, to resect the lobe in question. When the pathologic examination discloses carcinoma, the remainder of the lung is resected. There were 5 patients in this group with no postoperative complications.

5. Elective. This is the second largest group in our series. It includes all patients in whom a choice was made between resection and thoracoplasty, or some other surgical collapse procedure. About one-half of our lobectomies fall into this classification. As the indications for resection become better defined, it will probably become smaller. At present, the selection of patients for resection requires the combined wisdom of the medical and surgical team. It must be based upon a thorough knowledge of the patient's past reactions to his disease, an expert appraisal of his present status, and a wide experience in various forms of surgical therapy. It goes without saying that the patient must have had a prolonged period of observation under controlled conditions, and a thorough diagnostic work-up including the best in x-ray and bronchoscopic studies.

Among the considerations which have led us to do elective resections are the following:

A. Suspected, but not proved, tuberculous bronchial disease. It is becoming increasingly apparent that there is more tuberculous bronchitis than has been preoperatively diagnosed. Buckles and Neptune[6] have reported studies on 57 resected lungs. In 14 per cent, tuberculous bronchitis was diagnosed preoperatively, but it was found by the pathologists in 66.6 per cent. Likewise, Overholt and his co-workers[7] report in a study of 62 lungs resected after thoracoplasty failure, a pathologic finding of tuberculous bronchial disease in 64.5 per cent, as compared to a preoperative diagnosis in 37.1 per cent. Auerbach[8] found tuberculous bronchitis in 42.1 per cent of 1,000 consecutive autopsies on tuberculous patients. Jones and associates[9] conclude that bronchiectasis arises in reinfection disease in 50 per cent of fatal cases, and that it develops with surprisingly high incidence after primary tuberculosis in children. In our experience, patients whose disease remains more or less station-

ary, with no definite x-ray indication of cavity, yet a persistent or occasional positive sputum, are especially suspected of having tuberculous bronchial disease. The x-ray finding of "honey-combing" always leads us to suspect bronchiectasis. We believe that most such patients will not get well without a resection.

B. Patients whose past roentgenograms show a large amount of disease, which has partially healed with considerable scarring and fibrosis. Such lobes or lungs are likely to become the seat of much chronic pulmonary suppuration, even though adequately collapsed by thoracoplasty.

C. Cavities which have reopened after discontinuation of a therapeutically adequate pneumothorax are not likely to respond well to a second collapse procedure.

D. Cavities located near the hilum or mediastinum may either fail to respond to thoracoplasty, or require such an extensive one as to sacrifice a great deal of good lung tissue. In such cases, resection may prove to be the more conservative procedure.

E. Nonexpendable lung, frequently seen after long continued pneumothoraces, is often best treated by decortification of the "good" lobe, and a resection of the diseased one.

F. Tuberculomas of any considerable size, which have been under observation for some time without apparent change, should be considered for resection.

RESULTS

The immediate results in our series of 123 resections have been dealt with in considering the complications and indications (see Tables III and IV). We have not experienced a large number of late complications, such as reactivation, which others (notably Sweet[10]) have reported. We have continuously adhered to the principle that in resecting a lobe or a lung, we were merely removing the worst of the patient's tuberculosis, and thereby putting him in a favorable condition to control the remainder of the disease. We have insisted before accepting patients for resection, that they agree to undergo a prolonged period of bed rest following surgery. This practice we believe to be very important in preventing late complications.

Our patients have been referred to us from various physicians and sanatoriums, including many from out of the state. Follow-up studies, if they are

TABLE V. BARLOW SANATORIUM PATIENTS

	OPERATIVE RESULT			SPUTUM STUDIES			
OPERATION	NUMBER	MORBIDITY	MORTALITY	IMMEDIATE NEGATIVE	LATER NEGATIVE	TOTAL NEGATIVE	ALTERNATELY NEGATIVE AND POSITIVE
Lobectomy	15	2	0	11	2	13	2
Pneumonectomy	19	4	2	9	5	14	3
Total	34	6 (17.6%)	2 (5.9%)	20	7	27 (84.4%)	5

to be of any great significance, require that the patients be examined with similar techniques and under like conditions. Sanatoriums which have facilities for careful and extensive follow-up studies, are the most suitable sources for accumulating accurate information.

Among our patients are 34 from Barlow Sanatorium. Of these, 2 died in the hospital and did not return to the sanatorium (see Table V). Of the 32 who returned to the sanatorium, 20, or 62.5 per cent, had immediate and persistently negative sputum. By negative, we mean at least three consecutive pooled sputum and gastric washings injected into guinea pigs with negative results. An additional 7 patients converted to negative while in the sanatorium, making a total of 27, or 84.4 per cent, with persistently negative sputum. Five, or 15.6 per cent, had alternately positive and negative examinations, with the latest one negative in 4, and positive in one. In none of them has the sputum been continuously positive. Fifteen had surgery more than two years ago. Fourteen of these are working and in good health. One still has active disease in the contralateral lung. This disease was present at the time of surgery. In addition to the 2 patients who died, 4 patients developed complications following surgery. One had a bronchopleural fistula with empyema. She has closed the fistula and converted the sputum, and is awaiting additional surgery to eradicate the empyema. One had a pure tuberculous empyema appear a year after surgery. Sputum has remained persistently negative. One had a late appearance of disease in the remaining lobe after resection of the right upper and middle lobes. He has since had the pneumonectomy completed and has a negative sputum. One developed an ipsolateral spread, or reactivation, after segmental resection. She had two negative sputum and gastric examinations before the new disease appeared. She has since had a thoracoplasty with two negative examinations since the thoracoplasty.

It is interesting that one of the patients who died did well for five days and then developed x-ray evidence of contralateral disease. This disease continued to spread even though the patient was on streptomycin, and other antibacterial agents. He finally died sixteen days postoperatively, and the postmortem examination showed extensive disease in the contralateral lung. No tubercle bacilli could be cultured from the lung, and the microscopic slides were very puzzling to the pathologists. It was finally decided that the monocytic type of infiltration was most characteristic of a tuberculous reaction even though the picture was not entirely characteristic of that disease. It was classified as a death due to a tuberculous spread.

POSTRESECTION THORACOPLASTY

We feel that the question of the need for thoracoplasty following resection has not been entirely settled as yet. Early in our experience we performed few postresection thoracoplasties. Following receipt of reports from other clinics describing frequent reactivation in patients not protected with thoracoplasty, we have performed this operation routinely following pneumonectomies, and in se-

lected cases following lobectomy. Yet a study of results in our earlier cases who did not receive thoracoplasty does not give convincing evidence of the need for it in any but selected cases.

TABLE VI. THORACOPLASTY VS. NONTHORACOPLASTY

	NUMBER	EARLY COMPLICATIONS	LATE COMPLICATIONS		TOTAL	
			TUBERCULOUS	NONTUBERCULOUS	NUMBER	PER CENT
No postresection thoracoplasty	61	3	3	3	9	14.7
Lobectomy	29	0	2	0	2	6.9
Pneumonectomy	32	3	1	3	7	21.9
Postresection thoractoplasty	35	4	0	0	4	11.5
Lobectomy	10	2	0	0	2	20.0
Pneumonectomy	25	2	0	0	2	8.0

As will be seen in Table VI, 29 lobectomies and 32 pneumonectomies did not receive postresection thoracoplasty in the immediate period following resection. Of this number, two lobectomies and three pneumonectomies later had thoracoplasty performed because of complications. Early complications arising in patients receiving thoracoplasty were about the same as in those not receiving thoracoplasties. No late complications have yet appeared among the 35 patients who received thoracoplasty. One late empyema developed among the 61 patients who did not receive thoracoplasty. One late ipsolateral spread occurred in a patient who had a middle and upper lobe resection without thoracoplasty (see Barlow Sanatorium report). Three patients developed a nontuberculous complication which required thoracoplasty for its correction. All three were right-sided pneumonectomies. Two of them had symptoms due to marked shift of the mediastinum, and one had right-sided heart failure. But thus far there have been no reactivations of disease in any of the pneumonectomy patients on whom we did not perform a thoracoplasty. Neuhof and Nabatoff[11] recently published results of angiographic study of the form and function of the remaining lung after pneumonectomy. They observed that whether mediastinal shift was great or little, the change in form and function of the remaining lung is not so great as we have been led to expect.

SUMMARY

1. A series of 123 consecutive pulmonary resections on 122 patients performed between 1944 and the end of 1949 has been studied. Among them are 34 carefully followed patients from Barlow Sanatorium who have shown a sputum conversion of 85 per cent.

2. The hazards of pulmonary resection for tuberculosis are chiefly the hazards inherent in the disease itself, rather than in the operative procedure. In our experience, they have been markedly reduced by the effective use of antibacterial agents, such as streptomycin. In 35 patients not receiving streptomycin the morbidity was 48.6 per cent and the mortality 28.6 per cent. In 88 patients receiving streptomycin the morbidity was 12.5 per cent and the mortality 5.7 per cent.

3. Primary indications for resection which we have observed have been: (1) collapse failure, (2) destroyed lung, (3) chronic bronchial disease, (4) diagnostic problems, and (5) elective. In the latter group are such indications as suspected, but not proved, bronchial disease; cavities poorly situated for response to thoracoplasty; cavities which have reopened after discontinuation of successful pnuemothorax; tuberculomas; and cases in which there is extensive fibrosis and scarring of pulmonary tissue due to tuberculous disease. We are of the opinion that chronic tuberculous bronchial disease in its various manifestations is by far the most important indication for resection.

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PULMONARY RESECTION FOR TUBERCULOSIS WITH STREPTOMYCIN

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ALTHOUGH one of the first planned lobectomies for pulmonary tuberculosis was done by Dr. S. O. Freedlander, in 1934, at Cleveland City Hospital, there had been little enthusiasm for pulmonary resection here until the advent of streptomycin. Fifteen cases of resection were done prior to the use of streptomycin. The first patient is still living, with a negative sputum. However, because of a 20 per cent operative mortality rate and many complications, other forms of therapy were used whenever possible. We wish to review fifty-three consecutive cases of pulmonary resection with streptomycin performed for tuberculosis between March, 1947, and August, 1949. These comprise the cases selected for pulmonary resection from the 800 beds at Lowman Pavilion and Sunny Acres Hospital, the sanatoriums serving the City of Cleveland and Cuyahoga County. In a combined conference the medical and surgical staffs of both institutions determine all therapy, and selected this group for resection. Forty-six pneumonectomies and seven lobectomies comprise the fifty-three cases in this series. There were four deaths, a mortality of 7.5 per cent. Each patient in this series received streptomycin before, during, and after surgery. Following surgery, a modified thoracoplasty, as suggested by Overholt and associates,[1] was carried out after pneumonectomy and upper lobectomy. A permanent phrenic interruption was done following lower lobectomies.

The main indications for resection were those commonly used: (1) destroyed lung, (2) bronchial stenosis, and (3) collapse failure. Some of the cases fell under more than one heading, but the principal indication was chosen for classification in this study.

In the selection of patients resection was considered to be a radical, irrevocable, and occasionally hazardous procedure. It was felt that, in comparison to other types of therapy, it should offer the only or the best chance of cure. It must be remembered that functioning pulmonary tissue as well as diseased tissue is usually removed by resection. Where pulmonary function is borderline, overenthusiasm for resection may result in a respiratory cripple or death. In our cases, resection has not been used when it was felt that lesser measures of therapy would reasonably control the disease. Unless there was an urgent or specific indication for resection, collapse procedures have been employed. On the other hand, when it was felt that a collapse measure such as thoracoplasty was of questionable value, or where the patient would ultimately remain with one functioning lung, resection was the primary choice. This was done in preference to the performance of a multiple stage thoracoplasty, with its attendant dangers of spread, and the possibility of a later

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resection which in our experience is usually more difficult than an initial resection. Chronic bronchial stenosis was considered an absolute indication for resection, other factors permitting. One group of patients in whom it was thought that resection offered the best chance for successful treatment were the cases of unilateral acute pneumonic tuberculosis.

Table I illustrates the indications for resection and lists the number of cases in each category.

TABLE I

INDICATION		NUMBER OF CASES
1. Destroyed lung		26
A. Extensive acute pneumonic disease	16	
B. Nonacute disease	10	
2. Bronchial stenosis		14
3. Collapse failure		10
4. Tuberculoma		2
5. Hemorrhage		1
Total number of cases		53

Observations can be made best from a study of the results and complications of each group separately.

DESTROYED LUNG

Of the fifty-three cases, twenty-six were resected for a destroyed lung. By destroyed lung is meant a condition in which the pulmonary tissue of one lung or lobe shows complete or almost complete involvement by cavitation, extensive pneumonic disease, chronic fibrocaseous disease, or by a combination of these. Of the twenty-six patients, sixteen had extensive acute unilateral disease. The remaining ten were operated upon for fibrocaseous disease with cavitation. The only lobectomy in this group was done for a giant cavity.

In the ten nonacute cases, there were nine pneumonectomies. Five were in colored and four in white patients. Seven were women and two were men. The youngest was 15, the oldest was 43, and the average age was 29.6 years (see Table II). There were no complications in this group, either during or after surgery; at present all are living and well from two years to eight months postoperatively. One patient in this group was treated by left lower lobectomy for a giant cavity. Postoperative course was uneventful except for a small acute spread to the left upper lobe almost immediately after resection. This was controlled by a permanent phrenic nerve operation and pneumoperitoneum. He is working full-time one and one-half years after operation.

TABLE II

DESTROYED LUNG—TEN CASES			
Pneumonectomies	9	Lobectomy	1
White	5	Male	3
Colored	5	Female	7
Age Range:— 15 to 43 years			
Average:— 29.6 years			
Complications:—Spread to remaining lobe in lobectomy			

The group of sixteen acute cases comprises the largest number of patients under one category. It also contains three of the four deaths. All sixteen patients required pneumonectomy, although one was done for technical reasons after a lobectomy had been successfully performed. There were thirteen colored and three white patients in this group, and of these, nine were men and seven women. The youngest was 19, and the oldest 54 years of age. The average age was 32 years.

TABLE III

ACUTE PNEUMONIC DISEASE—SIXTEEN CASES

	Pneumonectomy	16	
White	3	Male	9
Colored	13	Female	7
	Age Range:—	19 to 54 years	
	Average Age:—	32 years	
Complications:	Wound Infections		2
Deaths	(3-16)		18.7%

In reviewing these cases, other than the three deaths and two wound infections, there is a gratifying lack of incidents to report. All patients received streptomycin prior to surgery, varying from twenty-six to eighty days. The average was 46.6 days of streptomycin. The dosage was 1 Gm. per day. The patients were observed carefully while on streptomycin, and when it was felt that they had obtained their optimum result from this therapy, operation was performed. All the patients had been very febrile prior to the institution of streptomycin therapy. Two cases continued to have a low-grade fever at the time of surgery. The others had been afebrile from seven to 165 days, an average of forty-three days, before surgery. The operative procedure itself was easier than in the chronic cases. Adhesions were usually not present, or when present were thin, delicate, and easily dissected, unless there had been previous infection. The postoperative course was no different than that of the more chronic cases. The majority of the patients had a relatively afebrile course. It was noted that almost invariably, about one week after operation, their general appearance was improved and they had a feeling of well-being which was apparent even at this early date.

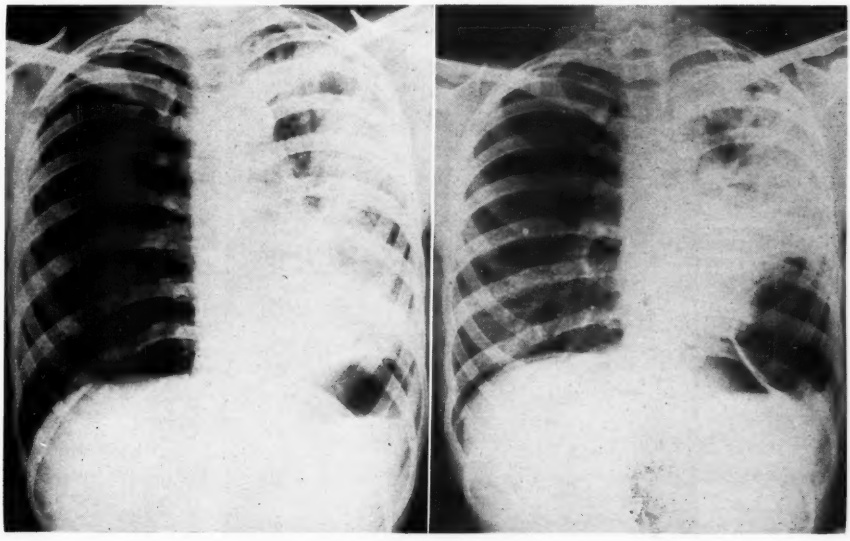
Of the sixteen acute patients, three died, a mortality of 18.7 per cent. Of the remaining thirteen patients, one was killed one year postoperatively following discharge from the hospital, when she was stabbed with a knife in the remaining lung. Twelve patients are living and well, from two and one-half years to six months postoperatively. It is interesting to note that while the mortality rate in the acute cases was 18.7 per cent, there was only one death in the thirty-seven nonacute patients, a mortality rate of 2.7 per cent. For this reason the three deaths in the acute group will be considered in some detail.

CASE REPORTS

The first death occurred in a Negro man, C. K., aged 23 years. The right upper lobe was the seat of dense, pneumonic disease with a four-centimeter cavity. The middle and lower lobes contained scattered disease. The dissection of the lung from the chest wall was difficult. At the end of the procedure, the blood pressure was 70/30, the patient having

received 1,200 c.c. of saline, 500 c.c. of plasma, and 1,500 c.c. of whole blood. He received an additional 500 c.c. of plasma and 500 c.c. of blood during the afternoon and died five hours postoperatively of acute pulmonary edema. This patient's pulmonary edema was probably due to the injudicious use of intravenous fluids.

The second death was that of B. K., a white man, aged 51 years, who had a first-stage thoracoplasty on Nov. 27, 1948, under local anesthesia, for a large cavity at the right apex. Postoperatively he had a massive bronchiogenic spread to the entire right lung. Right pneumonectomy was performed on Jan. 26, 1949. The pleural cavity was contaminated by the rupture of a small caseating focus as the lung was being taken from the wound. The postoperative course was febrile, but not too stormy, until seven days postoperatively, when the patient suddenly went into mild shock with a temperature of 38.5° C. He complained of pain in the right upper quadrant of the abdomen, with tenderness and slight spasm.

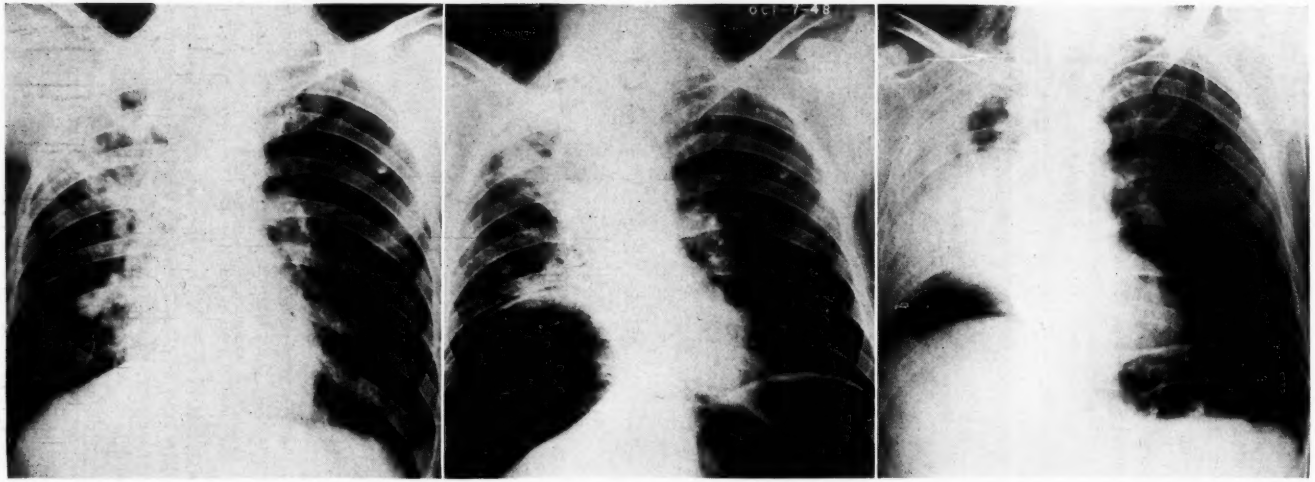


A. *B.*

Fig. 1.—*A*, Admission roentgenogram of the chest (March 6, 1947) on the first patient with acute disease which was resected. *B*, Preoperative roentgenogram (June 12, 1947) on the same patient.

Following this episode the patient developed cough and continued to run fever. The wound, which had been healed, broke down in small areas, about three weeks postoperatively. About the same time he started to raise sputum colored with old blood. A postpneumonectomy thoracoplasty was done in two stages, forty-six and forty-seven days after pneumonectomy. After this procedure the patient was in poor condition. He died seventy days after pneumonectomy with a bronchopleural-cutaneous fistula, infected wound, and spread to the contralateral lung.

The third death was that of J. F. R., a Negro man, aged 42 years. A diagnosis of pulmonary tuberculosis had been made in December, 1948. A roentgenogram of the chest revealed dense disease throughout the right upper lobe with considerable scattered disease in the middle and lower lobes. At operation, the apex of the lung was densely adherent and an apical cavity was opened in the dissection of the lung from the pleura. The pleural space was aspirated daily for two weeks after operation, with streptomycin and penicillin being instilled into the pleural cavity to prevent an empyema. The postoperative course was apparently uncomplicated when, on the twenty-fifth day after surgery, he had a sudden



A. *B.* *C.*

Fig. 2.—*A*, Admission roentgenogram of the chest (Oct. 2, 1947) on B. K., the second reported death. Cavitation is present. *B*, Prethoracoplasty roentgenogram on B. K. (Oct. 7, 1948). *C*, Postthoracoplasty roentgenogram on B. K. (Nov. 30, 1948) showing increase of disease at the right base which showed no change up to the time of pulmonectomy.

chill and elevation of temperature to 39.8° C., with a complaint of "soreness of abdominal muscles." The abdomen was diffusely tender. It was apparent that the patient had a bronchopleural fistula, and he began expectorating brown fluid. His course remained febrile in spite of therapy. Postpneumonectomy thoracoplasty was done on the forty-ninth postoperative day in an effort to obliterate the pleural space and to close the bronchopleural fistula. He quickly developed contralateral spread, remained febrile, and died eighty-three days following pneumonectomy.

In these two patients with bronchial fistulas, it was first thought than an empyema developed as a result of the spill of purulent material which occurred at the time of surgery and that the bronchial fistulas were secondary to this. These cases were treated for two weeks after surgery by daily complete aspirations of fluid from the pleural cavity and the instillation of 1 Gm. of streptomycin and 500,000 units of penicillin. There was no evidence of infection in the pleural fluid which was aspirated daily.

There were seven cases of pleural contamination in the thirty-seven nonacute cases, which were treated similarly with no untoward developments. For this reason we think that the pleural contamination was not the cause of the fatal sequence of events. Despite the careful closure and pleuralization of the bronchus in each case a bronchial fistula developed for some unexplained reason in these two. Bronchoscopy before surgery and examination of the specimens postoperatively revealed no bronchial disease.

There is evidence in these cases that when a bronchial fistula does occur it is quickly followed by a severe reaction. The reaction may be a sudden change in intrapleural pressure or signs of irritation to the pleura as manifested in B. K. on the seventh postoperative day, by mild shock, a temperature of 38.5° C., pain, tenderness and slight spasm in the right upper quadrant of the abdomen, and the development of cough. In the case of J. F. R., after an uneventful course, the patient on the twenty-fifth postoperative day, suddenly developed a chill, temperature of 39.8° C., and soreness of the abdominal muscles. In the future, any such episode shall be considered as evidence of opening of the bronchus. The patient shall be taken to surgery and an eight-rib thoracoplasty will be carried out, during which time the pleural cavity will be evacuated, the bronchus inspected and resutured if necessary. This procedure would perhaps be unnecessary if the thoracoplasty were done at the time of pneumonectomy, as advocated by Iverson and Skinner.[2] We believe that the combination of the two procedures is ideal, especially in acute disease. However, after a brief experience this combination has been judged too extensive for most of our patients.

In a recent case of pneumonectomy for tuberculosis, not included in this report, mild shock occurred on the fourth postoperative day. A sensation of air bubbling in the chest was felt by the patient, there was sudden deviation of the trachea to the unoperated side, and air was aspirated from the pleural space where only fluid had been obtained previously. Two days later her temperature, which had been normal during the postoperative period, went to 38.5° C. The procedure as previously outlined was carried out. No bronchial fistula was found. Her subsequent course has been uneventful.

The first opening of the bronchus may be only small or temporary, because our patients did not cough up bloody fluid, or have other evidence of a sizeable permanent opening of the bronchus at the time of the first acute episode. It may be impossible or not feasible to close a bronchial fistula as has been suggested. In these two cases there was a time lag of twenty-one days and thirteen days from the first symptoms of bronchial opening until it was definitely known that a bronchial fistula existed. If the bronchus were inspected immediately the defect might be so small that successful repair could be accomplished. In any case a complete eight-rib thoracoplasty done before gross infection had set in should offer a better chance of healing than after extensive infection and drainage had been done. Antibiotics are also more effective early. The chances of thoracoplasty wound infection after gross infection of the pleural space are increased because of infection extending from the pleura through the pneumonectomy rib defect into the soft tissues of the chest wall.

BRONCHIAL STENOSIS

Fourteen patients had bronchial stenosis. Eight had stenosis of the mainstem bronchus and six of an upper lobe bronchus. In all the diagnosis was made preoperatively by bronchoscopy and was the primary indication for resection. Lobectomy was planned in four of the cases with upper lobe bronchial stenosis. However, at operation a significant amount of disease was found in the lower lobe, and it was felt that it was dangerous to allow this to remain. Therefore, pneumonectomy was done in these cases.

Of these patients thirteen were female and one male. Three were colored and eleven white. The youngest was 26, the oldest 57, and the average age was 34.4 years (see Table IV). In all cases the bronchial stenosis and pulmonary disease were mainly chronic in type. It was noted at operation that the bronchus was difficult to dissect, due to a peribronchial inflammatory reaction which was more marked than in any other group. There were no complications during or after surgery, with the exception of one wound dehiscence. The wound was resutured and healed without infection. All patients in this group are living and well, sputum negative, from two years and ten months to eight months after surgery.

COLLAPSE FAILURE

Ten patients were operated upon for collapse failure. Only five were reported to have bronchial stenosis by pathologic examination of the specimens. Five were failures of thoracoplasty to close the cavity. Three had been treated

TABLE IV

BRONCHIAL STENOSIS—FOURTEEN CASES			
	Pneumonectomy	14 Cases	
White	11	Female	13
Colored	3	Male	1
	Age Range:—	26 to 57 years	
	Average Age:—	34.4 years	
	Complications:	None	

with pneumothorax, pneumoperitoneum and phrenic crush, and two were failures of pneumothorax alone. There were six pneumonectomies and four lobectomies in this group.

TABLE V

COLLAPSE FAILURES—TEN CASES			
Pneumonectomies	6	Lobectomies	4
Collapse Used:			
Thoracoplasty	5	Pneumothorax	2
Pneumothorax, Phrenic Crush and Pneumoperitoneum			3

These patients all had a fair trial of one or more of the collapse procedures. The shortest period of collapse was six months in a patient treated by thoracoplasty. The longest was thirty-six months (a combination of pneumothorax, phrenic crush, and pneumoperitoneum). The average duration of collapse was nineteen months. One of the patients was colored and nine were white. The youngest was 22 years of age, the oldest 48, and the average age was 31.5 years (see Table VI). The resections following thoracoplasty were technically more difficult than the average. One of the cases was complicated preoperatively by an effusion positive for tubercle bacilli, and infected thoracoscopy sinus tracts.

There were three tuberculous wound infections in this group, and one death. Two of the wound infections were excised at the time of thoracoplasty and healed per primum. The third occurred in the case that died. Death was due primarily to respiratory insufficiency in one of the lobectomies. One patient was living and well for two years, sputum negative, and with no sign of activity of the disease. She died suddenly at home one night before she could be seen by a physician. An autopsy was not obtained. One has recently developed a cavity in the remaining lung one year after resection. One died seventeen months after surgery of cor pulmonale; the remaining six cases are living and well, sputum negative, from thirty to ten months postoperatively.

TABLE VI

COLLAPSE FAILURES—TEN CASES			
White	9	Female	7
Colored	1	Male	3
Age Range:—		22 to 48 years	
Average Age:—		31.5 years	
Complications:	Wound infections		3
	Deaths		1

TUBERCULOMA

There were two cases which were interpreted as tuberculoma. Both cases had positive sputum and other signs that the lesion had developed caseation. Both were female, one colored and one white. Each was treated by lobectomy and both had uneventful postoperative courses. They are both living and well, sputum negative, eight and eleven months after resection.

HEMORRHAGE

One case was done for hemoptysis. The patient was a 28-year-old Negro man for whom a thoracoplasty had been planned and the first stage carried out. Several days later, severe hemoptysis occurred and pneumonectomy was performed as a life-saving procedure. Pathologic examination of the lung revealed erosion of the cavity into an adjacent blood vessel. The patient also had an extensive caseous pleurisy which was decorticated. The postoperative course was stormy, but without major complication. He has had no pulmonary spread of the disease seventeen months after surgery, but he did develop tuberculous osteomyelitis of the left foot and ankle, for which an amputation was done in September, 1949.

SUMMARY

Fifty-three consecutive cases of pulmonary resection for tuberculosis are presented. Four deaths occurred, a surgical mortality of 7.5 per cent. There were three deaths in the sixteen acute cases, a mortality of 18.7 per cent. All of the patients received streptomycin before, during, and after surgery. Of the forty-nine patients who survived, none developed complications such as bronchopleural fistula or empyema, and only one has developed a spread on the contralateral side. Although the mortality was higher in the patients with acute pneumonic disease, it is felt that in these cases especially, resection offers almost the only chance of recovery. Observation in the patients who developed bronchopleural fistulas has led us to the conclusion that the opening of the bronchus may be small at first, and may be characterized by mild shock, upper abdominal pain, and fever. It is our belief that the results of this complication may possibly be prevented by immediate thoracoplasty with inspection and resuturing of the bronchus, if possible. To date, the results of pulmonary resection with streptomycin have been impressive. We feel that this procedure is now an important part of our armamentarium in the treatment of patients with pulmonary tuberculosis.

The authors are indebted to Dr. Sidney E. Wolpaw for advice rendered during the preparation of this paper.

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PRIMARY NEUROFIBROSARCOMA OF THE DIAPHRAGM

Report of Two Cases

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THE unique character of primary diaphragmatic tumors is intriguing to both the clinician and the pathologist because of the combined problem of diagnosis, therapy, and cell derivation.

While several different cell types have been encountered, a search of the literature fails to reveal any primary tumor of the diaphragm classified as neurofibrosarcoma. It seems worth while, therefore, to record two personal cases, believed to be the first so reported.

INCIDENCE OF PRIMARY DIAPHRAGMATIC TUMORS

Scott and Morton[1] collected thirty-three primary tumors of the diaphragm which had been reported between 1868 and 1946. Four of these were not established by operation or autopsy and have been discarded. This leaves a total of twenty-nine proved cases. Since 1945, Rosenthal and Frissell,[2] Van Alstyne,[3] Branwood and Glazebrook,[4] and Grow, Bradford, and Mahon[5] have contributed four additional tumors. The two cases of the present report increase the total to thirty-five. Seventeen of the thirty-five tumors were classified as benign and eighteen as malignant.

The cell types were recorded as follows:

Table I

BENIGN		MALIGNANT	
Lipoma[6-9]	4	Fibrosarcoma[2, 20-24]	6
Cyst[1, 10, 11]	3	Rhabdomyosarcoma[25, 26, 27]	3
Fibroma[12, 13]	2	Myosarcoma[28]	1
Chondroma[14]	1	Leiomyosarcoma[27]	1
Angiofibroma[15]	1	Fibromyosarcoma[29]	1
Hemangioendothelioma[3]	1	Round-cell sarcoma[30]	1
Lymphangioma[16]	1	Undifferentiated sarcoma[31]	1
Neurofibroma[17]	1	Mixed cell sarcoma[4]	1
Rhabdomyofibroma[18]	1	Hepatoma from embryonic cell rest[32]	1
Fibromyoma[19]	1	Neurofibrosarcoma (present report)	2
Fibroangioendothelioma[5]	1		
Total	17	Total	18

Surgical excision was performed in fourteen cases. While there is a paucity of information regarding postoperative survival times, the results which have been reported are given in Table II.

CASE REPORTS

Case 1.—H. Y., a 56-year-old white man, was referred to us* in February, 1946. In 1940, the patient was admitted to the Alameda County Hospital with the complaints of swelling of the right ankle and knee, and fleeting pains with stiffness in the joints of the right wrist,

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*By Dr. Kenneth Jenkins.

TABLE II

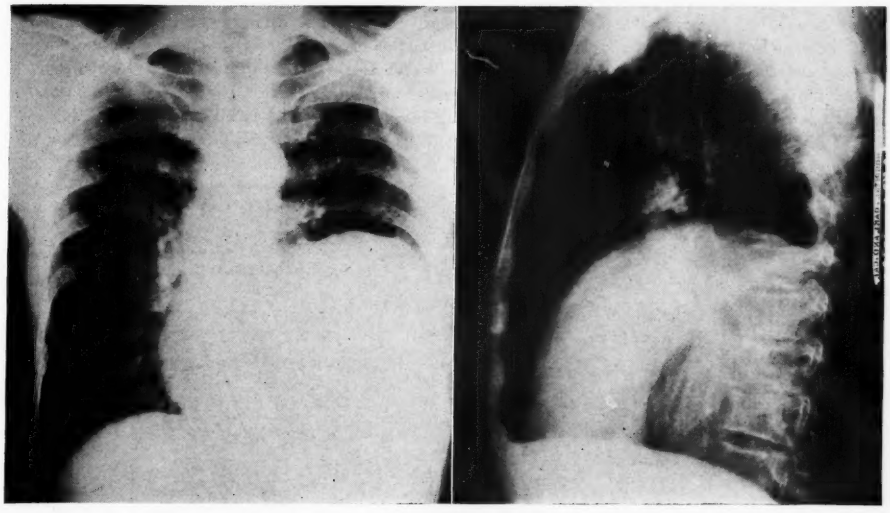
AUTHOR	DATE	TYPE	SIDE	RESULT
Primary Benign Tumors				
1. Bonamy[13]	1912	Multiple fibromas	Right	Recovery
2. Soderlund[6]	1937	Lipoma	Left	Recovery
3. Kinsella[19]	1939	Fibromyoma	Right	Recovery
4. Butler[10]	1939	Cyst	Left	Recovery
5. Arkless[18]	1942	Rhabdomyofibroma	Left	Recovery, died 7 years postop. from causes other than tumor
6. Soto[7]	1943	Lipoma	Right	Recovery
7. Robson and Collis[11]	1944	Cyst	Right	Recovery
8. Klassen, Patton, and Bemen[17]	1945	Neurofibroma	Right	Recovery, well 7 months postop.
9. Scott and Morton[1]	1946	Cyst	Left	Recovery
Primary Malignant Tumors				
1. Gross[20]	1911	Fibrosarcoma	Left	Recovery, died 7 months postop. from recurrence
2. Sauerbruch[29]	1913	Fibromyosarcoma	Left	Recovery
3. Gale and Edwards[32]	1939	Hepatoma (embryonic cell rest)	Right	Recovery, well 7 months postop.
4. Ackermann[21]	1942	Fibrosarcoma	Right	Recovery
5. Samson and Childress (Case 1)	1946	Neurofibrosarcoma	Left	Recovery, well 4 years postop.

fingers, and toes. Roentgenograms of the hands and feet at that time were normal. The joint symptoms had subsided somewhat during the four-year period from 1941 to 1945. In 1946, only careful questioning revealed symptoms referable to the chest. The patient had had a chronic cough for many years which had become more pronounced during the previous year. For possibly one year the patient admitted to mild dyspnea on exertion which he had completely ignored and, on bending forward, a sense of fullness and weight in the left chest. The cough had not been productive and there was no blood spitting, wheezing, or pain in the chest.

Physical examination showed a thin, sallow-complexioned man appearing older than the stated age. Distinct clubbing of the fingers was present which, the patient said, had been called to his attention three years previously by members of the family. The left lower chest showed slight limitation or motion. There was dullness posteriorly from the seventh rib downward which was not changed by deep inspiration. The right lung was normal. The heart sounds were normal and the blood pressure was 130/80. The liver and spleen were not palpable. Details of the roentgenographic findings are given in Figs. 1 and 2.

The only abnormal laboratory finding was a coagulation time of eighten minutes. Vitamin K was given prior to surgery. The left lower chest was aspirated and no fluid was obtained. The needle encountered firm resistance. Among other intrathoracic lesions, a diaphragmatic tumor was considered.

Left posterior thoracotomy was performed on March 14, 1946. Through a curved incision, the eighth rib and a posterior segment of the seventh rib were removed. The pleural cavity was opened exposing a large nodular tumor occupying the entire left lower pleural cavity. The tumor was firm and had a poorly developed capsule. Many large veins, almost sinuses, coursed over the surface of the tumor. These passed through numerous firm adhesions attached posteriorly to the parietal pleura and superiorly to the diaphragmatic surface of the left lower lobe. There was no adherence to the pericardium. The left lower lobe and lingula were atelectatic from pressure. The diaphragmatic surface of the lower lobe was separated from the tumor by sharp dissection. This resulted in considerable oozing and leakage of air. Numerous suture ligatures were necessary to obliterate the large venous sinuses and prevent a massive hemorrhage from the surface of the tumor. After separating all adhesions the tumor was partially delivered through the incision and the inferior surface inspected. The base was concave and arose from the central tendinous portion of the diaphragm. The superficial layer of the tendinous portion was peeled away with the tumor leav-



A. *B.*

Fig. 1, *A* and *B* (Case 1).—Roentgenogram, frontal and lateral projections. The mediastinum and heart are not displaced. The density at the left base has a rounded upper border. Fluoroscopically, this border descended slightly on deep inspiration. Films made with the Potter-Bucky grid showed no evidence of bony erosion.

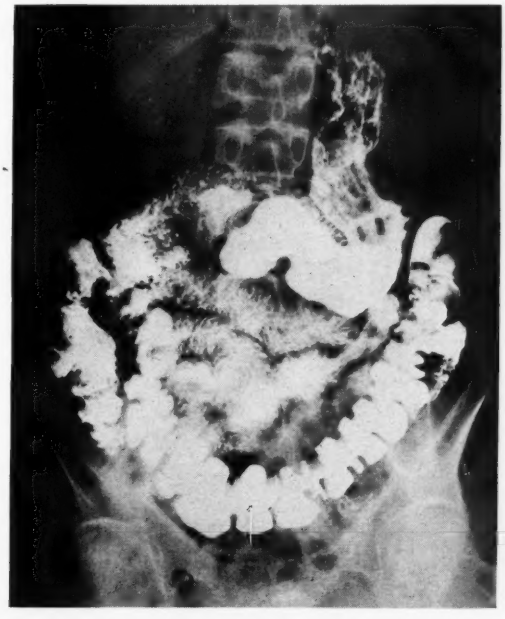


Fig. 2 (Case 1).—A simultaneous barium study of the stomach and colon shows no evidence of displacement or of pressure defects. This was believed to rule out both eventration of the diaphragm and an infradiaphragmatic mass.

ing several small perforations into the peritoneal cavity. The diaphragm was opened and its inferior surface inspected. There was no evidence of neoplastic extension. The diaphragm was then closed in two layers with interrupted silk. The torn surface of the lung was repaired and the lower lobe brought to full expansion under positive pressure. The pleural cavity was not drained. During and immediately following surgery a total of 2,000 c.c. of whole blood and 500 c.c. of plasma were given. The patient left the operating room in excellent condition.

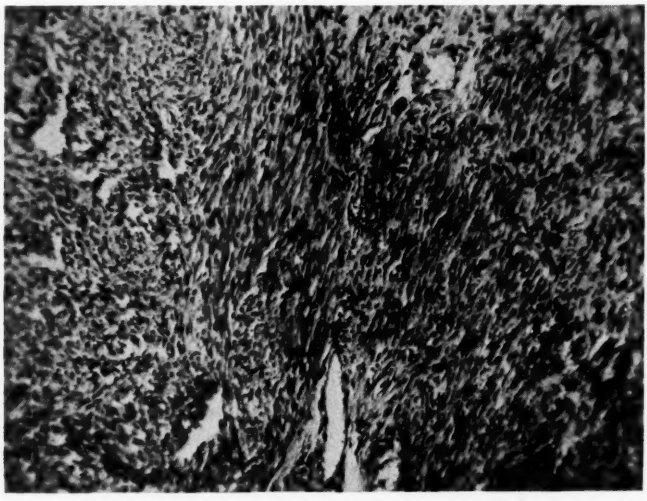


Fig. 3 (Case 1).—Photomicrograph ×100. There is characteristic palisading with neurogenous elements intermixed with fibroblasts. There is round cell infiltration showing some inflammatory change.

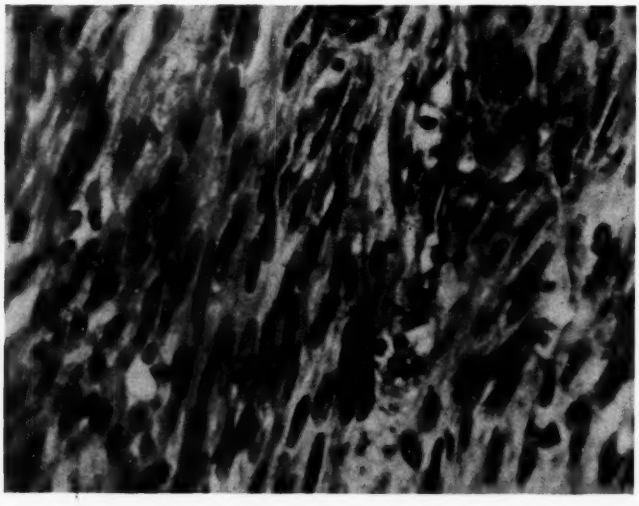


Fig. 4 (Case 1).—Photomicrograph ×500. The elongated and fusiform-shaped spindle cells with numerous mitotic figures are characteristic of metaplasia into true sarcoma.

Postoperatively, there occurred a transient atelectasis of the left lower lobe. Several aspirations of fluid from the pleural cavity were necessary. The patient was discharged home on the twelfth postoperative day.

The tumor was roughly ovoid, measuring 20.5 by 15.0 by 10.0 cm. and weighing 1,755 grams. The upper end was slightly pointed and the lower surface was flat measuring 12.5 by 10.0 cm. The tumor was firm and surrounded by a fibrous capsule measuring from 3 to 6 mm. in thickness, except near the flattened surface where the capsule broadened to a depth of 3 cm. In this portion of the capsule was an isolated nodule measuring 3 by 2 by 2 cm. which was slightly softer than the remainder of the tumor mass. The cut surface showed interlacing bands of white and pinkish-white tissue. One small cystic area was demonstrated. Microscopic examination* showed a fibrous and neural stroma with scattered areas of necrosis and degeneration. In some areas, there was metaplasia of the fibrous elements into true sarcoma. In these regions the cells were hyperchromatic, spindle-shaped, and moderately pleomorphic with fairly frequent mitotic figures (Figs. 3 and 4). The small soft nodule described previousy was composed almost completely of this type of cell.

Fig. 5 (Case 2).—Roentgenogram, frontal projection with Lipiodol filling. There is a large density obscuring over one-half of the right lung field. The upper border is rounded. On the original film no endobronchial obstruction was seen. Atelectasis of the right middle and right lower lobes was suggested. (No other films were suitable for reproduction.)

The patient convalesced slowly but progressively from operation. During the nine succeeding months he gained at least fifteen pounds. The clubbing of the fingers gradually receded, with return to normal in approximately six months. Almost from the day of operation he completely and permanently lost all stiffness and pain in the smaller joints. Four years following surgery the patient was working steadily. He had a morning cough productive of a slight amount of mucopurulent sputum. Thorough physical and roentgenographic examinations showed no evidence of recurrence of the tumor.

CASE 2.—E. L., a 50-year-old white housewife, was admitted to the San Joaquin General Hospital in September, 1946, because of increasing dyspnea over a period of six months. In March, 1946, she had been placed on digitalis therapy. One month later she noted ankle edema, more pronounced in the afternoon. During the month prior to admission she lost

*By Dr. Gertrude Moore.

twenty pounds and suffered from anorexia, constipation, increasing weakness, and fatigability. On September 4, a dull aching pain appeared in the right upper abdomen and right shoulder. This pain was accentuated by deep breathing. There was no hemoptysis or cough.

Physical examination revealed a markedly obese female who was orthopneic. The temperature was 101.6° F., the pulse 100 per minute, and the respirations 32. There was an inspiratory lag of the right hemithorax and absent breath sounds with dullness to percussion over the lower one-half posteriorly. The abdomen was pendulous and palpation in the right upper quadrant provoked pain. A one plus pitting edema of the ankles and pretibial areas was present. No clubbing of the digits was noted.

The erythrocyte count was 4,100,000, the hemoglobin was 11 Gm., and the leucocyte count was 12,000. The Kline serologic test was negative, and the urine revealed a one plus albumin. Circulation time by the Decholin method was eight seconds and by the ether method seven seconds.

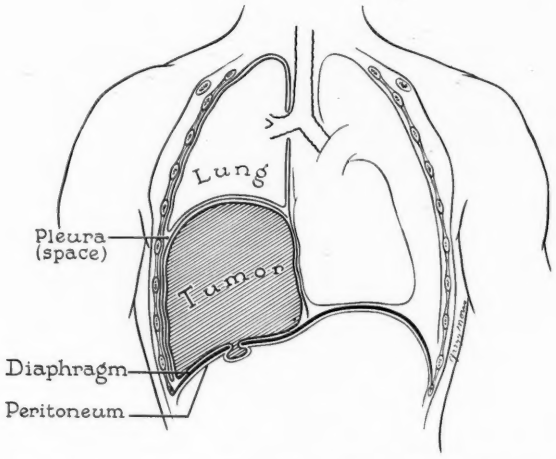


Fig. 6 (Case 2).—Schematic drawing of the situation seen at post-mortem examination. The tumor is entirely extrapleural and has pushed the heart to the left. The pedicle has pierced the diaphragm forming a 2 cm. tumor nodule lying extraperitoneally below the diaphragm.

Details of the roentgen films are shown in Fig. 5. Fluoroscopic study indicated that the mass moved synchronously with the right hemidiaphragm. Films following the induction of a pneumoperitoneum disclosed the mass to be supradiaphragmatic. Bronchograms showed no evidence of intrabronchial disease, although atelectasis of the right lower lobe was suggested.

Three attempts at right thoracentesis failed to obtain any free fluid. Bronchoscopy disclosed a horizontal take-off of the right-stem bronchus with an upward swerve of its distal portion. There was moderate narrowing of the lumen throughout.

It was felt that the patient had an extrapulmonary mass originating in the right lower hemithorax, and a diaphragmatic tumor was considered. Exploratory thoracotomy was advised but the patient died suddenly before surgical intervention was undertaken. No single cause of death was discovered, although the patient's sudden death was not surprising in view of the decreased pulmonary function, poor cardic reserve, and obesity.

At autopsy there was complete atelectasis of the right lower lobe and partial collapse of the middle and upper lobes. A tumor measuring 23 by 22 by 11.5 cm. and weighing approximately 3,000 grams completely filled the right lower hemithorax up to the level of the sixth rib posteriorly. When viewed alone it appeared to be a perfect mold of the space it occupied with intermittent grooves for the ribs. The inferior surface was concave and at-

tached by a ½ cm. pedicle which pierced the hemidiaphragm through its tendinous portion and expanded into a tumor nodule 2 cm. in diameter below (Fig. 6). The tumor was entirely extrapleural and extraperitoneal. The inferior mediastinum was pushed to the left and was connected to the tumor by dense fibrous tissue which contained numerous large veins. There were no venous connections with the lung. The growth was firm and on cut sections revealed scattered areas of xanthochromia.

The histologic picture* presented the same cellular elements as found in Case 1 (Fig. 7).

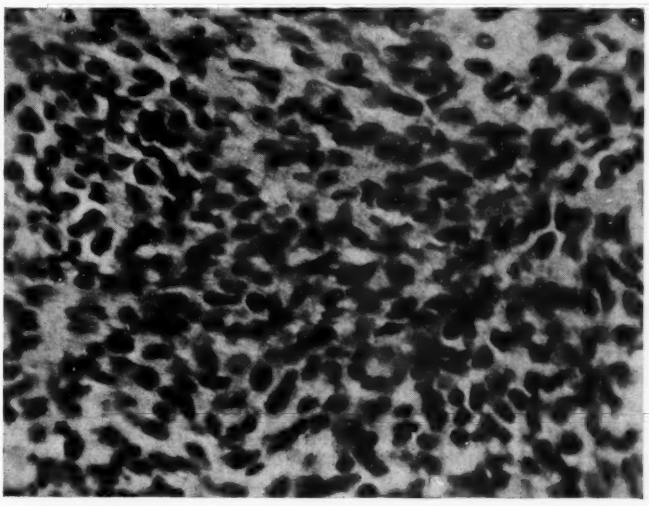


Fig. 7 (Case 2).—Photomicrograph ×500. The neurogenous elements are evident. There is extensive pleomorphism of the cells with some attempt at palisading. There is obvious malignant degeneration and mitotic figures are numerous.

COMMENT

Of particular interest was the effect of surgery on the joint symptoms and clubbing of the fingers in Case 1. Van Hazel[33] discussed joint manifestations in a group of seven patients with intrathoracic tumors and cited two in whom the joint symptoms abruptly disappeared following operation. Klassen's[17] patient showed no clubbing but suffered from arthralgia and joint-swelling in the hands and feet. These symptoms disappeared following operation. More recently, Berg[34] reported six additional cases in which dramatic improvement from arthralgia and clubbing of the digits followed removal of intrathoracic tumors. Of the nine cases thus collected, three were benign tumors of the mediastinum, one was a benign tumor of the diaphragm, one was a benign tumor of the lung, and four were primary carcinomas of the lung.

It is recognized that the majority of patients with intrathoracic tumors do not manifest hypertrophic pulmonary osteoarthropathy. This discrepancy is due to unknown or unrecognized factors. Van Hazel and others believe there is evidence that chronic anoxemia may be an important factor in the development of clubbing. He postulated that the anoxemia may be due to

*Described by Dr. Paul Michael.

neoplastic involvement of, or direct pressure on, hilar pulmonary vessels, particularly the veins. A comparison of the findings in our two patients suggests, however, that neither the pressure hypothesis nor anoxemia per se can fully explain the occurrence of joint manifestations. The first patient showed no clinical signs of anoxemia, although the original complaints of arthralgia antedated the discovery of the tumor by nearly six years. The second patient was obviously anoxemic. She had orthopnea. The tumor was larger and extended higher in the hemithorax. There was more extensive atelectasis and obviously greater pressure on the pulmonary hilum, particularly the inferior pulmonary vein, yet joint symptoms failed to become manifest. It is not inconceivable that this tumor grew rapidly and that the patient died before sufficient time had elapsed for the development of arthralgia or clubbing.

Another possible factor bearing on the development of joint manifestations concerns the blood circulation. While both tumors described previously were exceptionally vascular, there was one important difference in venous drainage. In Case 2 (without arthralgia) the venous return was mainly into the mediastinum, thus the venous blood of the tumor emptied into that of the greater circulation. In Case 1 (with arthralgia) large venous sinusoids connected the tumor with the pulmonary circulation as well as with the parietes. Thus, the main volume of reduced hemoglobin from the tumor probably emptied into the oxygenated blood of the pulmonary venous circulation. This condition may well have had the same circulatory effect as an intrapulmonary arteriovenous fistula. Patients with the latter lesion also frequently exhibit clubbing of the digits.

Fried[35] has expressed the opinion that hypertrophic pulmonary osteoarthropathy is not unlike acromegaly. He has observed the former condition in patients with bronchiogenic carcinoma; then demonstrated hyperplasia of the eosinophilic cells of the anterior hypophysis at necropsy. Fried thus suggests that the motivating disorder is dispituitarism which is provoked by disease of the lungs.

DISCUSSION

Tumors of the diaphragm have now progressed from an academic to a practical category. They are uncommon but important from a therapeutic standpoint. In keeping with the contemporary medical dictum of "constant awareness," we emphasize that at one stage malignant diaphragmatic tumors are amenable to surgical excision. They remain only to be diagnosed during the docile interval.

The signs and symptoms are governed by the size and location of the tumor on the diaphragmatic surface. As a rule, they do not appear until the lesion has attained considerable magnitude. Dyspnea, cough, and thoracic discomfort may result from pressure atelectasis. Other symptoms less commonly encountered have been gastrointestinal upsets, shoulder pain, effusions, and hemoptysis. The work load of the heart may be increased by a large ex-

cessively vascular tumor, in effect, the introduction of a new circulatory system. In patients whose cardiac reserve is otherwise limited (such as in Case 2), this additional factor may well lead to cardiac decompensation and exitus.

Roentgenograms and fluoroscopy will aid in localization and in study of the pathologic dynamics of the mass. If there is roentgen evidence of a tumor adjacent to eroded vertebrae, thought should be given to intraspinal Pantopaque studies to rule out intrathoracic meningocele.[36] An anomalous lobe of an otherwise normal liver[37] may roentgenographically mimic a diaphragmatic tumor. It may be impossible, however, to delineate between a supra- and infradiaphragmatic position without utilizing pneumoperitoneum.

When a tumor occupies the supradiaphragmatic position, it should be identified as extra- or intrapulmonary. Bronchoscopic exploration eliminates visible endobronchial extensions of an intrapulmonary tumor and affords opportunity for the cytologic study of bronchial secretions. Bronchographic mapping may reveal distortion of the tracheobronchial tree due to extrinsic pressure. If distortion is present and there is no endobronchial pathology, an extrapulmonary tumor is strongly suggested. Pneumothorax may be instituted but the roentgenographic interpretation should be cautious. A tumor attached to an atelectatic pulmonary base may present a homogeneous shadow which makes the differentiation between intra- and extrapulmonary positions difficult. If the pneumothorax is adequate thoracoscopic inspection may be considered but, in general, both pneumothorax and thoracoscopy are discarded procedures in such a situation.

In the final analysis, exploratory thoracotomy always should be undertaken both for diagnosis and for treatment unless the operative risk is prohibitive.

SUMMARY

1. Two cases of primary neurofibrosarcoma of the diaphragm are described. No other tumor of this particular cell type involving the diaphragm has been found in the literature.

2. In both patients, diaphragmatic tumor was considered in the differential diagnosis. The first patient has remained well for four years following surgical removal; the second patient died suddenly before exploration could be carried out.

3. Thirty-three additional examples of primary tumor of the diaphragm have been collected from the literature. Of this total of thirty-five, seventeen were considered to be benign and eighteen malignant.

4. The relationship of arthralgia and clubbing of the digits to intrathoracic tumors is discussed.

5. Diagnostic approaches to diaphragmatic tumors are enumerated.

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THE COMPLICATIONS OF STELLATE AND THORACIC SYMPATHETIC NERVE BLOCKS

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STELLATE GANGLION BLOCK

DENERVATION of the stellate ganglion and the thoracic sympathetic ganglia by block with local anesthetic drugs is a common practice in the diagnosis and therapy of an increasing number of diseases and injuries. It is inevitable that some undesirable complications result from the widespread utilization of the procedures. It is the purpose here to outline in some detail the nature of these complications and the factors responsible for their development. The need for a realistic appraisal of the potentialities for harm in completing stellate ganglion and thoracic sympathetic blocks is apparent on anatomic grounds alone. There is a constant proximity of important structures which cannot be invaded by the exploring needle with impunity.

Anatomy.—The anatomy of the stellate ganglion must be reviewed briefly. A bilateral structure, it originates from the fusion of the first thoracic sympathetic ganglion and the inferior cervical ganglion to form a semilunar mass approximately 2.5 cm. in length and 0.5 cm. wide in the majority of specimens. This general configuration is fairly constant although the actual shapes of the ganglia vary widely. Posteriorly, the stellate ganglia lie on the lateral surface of the first thoracic and seventh cervical vertebrae between the head of the first rib and the vertebral artery at its junction with the subclavian. The carotid sheath containing the carotid artery, jugular vein, and vagus nerve lies anteriorly and slightly lateral. The phrenic nerve, lying in the scalenus anticus muscle is lateral and the bodies of the first thoracic and seventh cervical vertebrae are medial. The sympathetic chain and the ganglion lie on the deep fascia which covers the anterior surface of the longus capitus, longus colli, and scalenus anticus muscles.

The stellate ganglion is illustrated in Fig. 1 to point out the mechanism of the most important and serious complications of nerve block in this region. Particular reference is made to the apex of the lung immediately lateral to the stellate ganglion and the exposed intervertebral foramina of the cervical spine which offer an avenue to subarachnoid injection of local anesthetic drugs.

The position of the apex of the lung makes it entirely feasible to induce pneumothorax if the advancing needle is somewhat off its course. It is interesting although possibly unnecessary to point out, that induction of a pneumothorax by allowing air to leak in between the layers of pleura from the external environment is not very easy to accomplish in the scarred apical position of the adult lung. It appears more likely that the pneumothorax is the consequence of

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pulmonary perforation with an air leak from the lung to the pleura. The belated awareness of symptoms and the occasional instance of tension pneumothorax support this concept. Another point of practical importance is the actual height of the apex of the lung. Ordinarily, the apex of the lung is considered to be level with the first rib posteriorly or 4 cm. above the clavicle anteriorly. Simple observation and some thought will indicate that these guides are approximations at best. The apex of the lung is mobile when it is not adherent to the chest wall and moves *down* with inspiration, a point of some importance if the phase of respiration is to be employed as assistance in minimizing the danger of pneumothorax. The apex of the lung also varies in position with disease and body habitus. These are anatomic factors which should be remembered in performing stellate ganglion block.

The mechanism of subarachnoid anesthesia as a complication of stellate block is more easily understood. The dura may be perforated in an intervertebral foramen or in areas where its extension peripherally about a somatic nerve makes it peculiarily liable to injury and perforation.

The presence of other structures shown in the diagram suggests further possible complications. However, none of these, except for intravascular injections, has proved important or serious in executing stellate block.

Techniques.—The techniques of stellate block, as described in the literature, are varied and large in number.

The classic technique is that introduced in this country by Labat as modified by White.[1] This has since been largely replaced by many anterolateral, lateral, or anterior approaches making use of Chassaignac's tubercle or the cricoid cartilage as landmarks.

In the anterolateral approach used by Volpitto and Risteen[2] a wheal is raised 2 cm. inferior to Chassaignac's tubercle and 1 cm. above the midclavicular point. An 8 cm. needle is introduced downward and medially at a 45° angle with the sagittal plane of the body to encounter the transverse process of the seventh cervical vertebra or the first rib at a depth of 5 to 6 cm. The needle is withdrawn and the angle changed to 80 to 90°. It is then advanced to 6 to 8 cm. where it should encounter the body of the first thoracic vertebra. This approach has been varied by individuals with a radius of 3 to 4 cm. for the skin wheal. Still other variations involve encountering Chassaignac's tubercle first and then redirecting the needle toward the seventh cervical vertebral body.

Murphey[3] described another "anterior approach" with a puncture site at the lateral edge of the scalenus anticus muscle at the level of the cricoid cartilage. A spinal needle is directed with the point posteriorly at an angle of 5 to 15° with the horizontal. The needle, passing behind the carotid sheath and superior to the apex of the lung, impinges on the stellate ganglion or the body of the seventh cervical vertebra.

Fitspatrick and Higdon[4] described the simple technique in which the skin wheal is made over Chassaignac's tubercle. The needle is inserted directly toward the tubercle and is then redirected slightly anteriorly and inferiorly to the body of the seventh cervical vertebra.

Ochsner and DeBakey[5] prefer a modification of Leriche's technique. Using a skin wheal 1 cm. medial to the upper border of the midpoint of the clavicle, a needle is inserted at a 45° angle 6 to 7 cm. between the vertebral and carotid arteries. They have also described an approach lateral to the vertebral arteries.[6]

Findley and Patzer[7] described an anterior or paratracheal approach. The skin wheal is made two fingerbreadths above the sternoclavicular junction just medial to the carotid artery. The needle is inserted straight down to the transverse process of the seventh cervical vertebra and then after withdrawing 2 mm. the injection is made.

The apparently endless varieties of methods which have been reported for completing stellate ganglion block have been successful in producing sympathetic paralysis. The important aspect of selecting a technique, in view of the ease in obtaining effective blockade, is the method which is least encumbered by untoward sequelae. Many of the excellent reports available are concerned exclusively with therapeutic effect or deal with such small numbers that no reasonable delineation of the complications is possible.

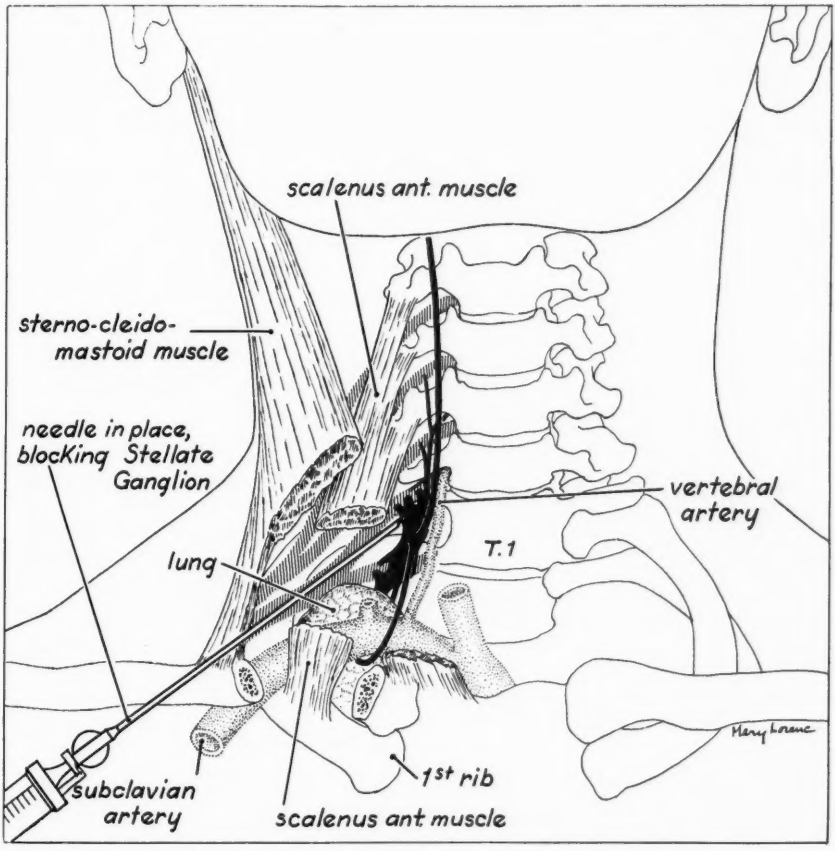

Fig. 1.—Diagrammatic representation of important structures associated with stellate ganglion block.

To ascertain the influence of technique upon the incidence and the nature of complications, an unselected series of 186 consecutive stellate ganglion blocks was studied (Table I). Blocks were performed by visiting and resident staff in a hospital caring for indigent patients only. The major complications with reference to the influence of technique are summarized in Table II. Although

TABLE I

DISEASE	NUMBER OF BLOCKS	NUMBER OF PATIENTS	CLINICAL RESULTS		
			GOOD	FAIR	POOR
1. Peripheral vascular disease	54	27	16	1	10
2. Asthma	69	41	25	7	9
3. Postmastectomy edema	4	2	1	1	0
4. Causalgic states	33	16	8	3	5
5. Angina	5	4	0	3	1
6. Cerebral accidents	10	10	1	4	5
7. Phantom pain	2	2	0	1	1
8. Carcinoma, tongue	2	1	0	1	0
9. Herpes zoster	1	1	1	0	0
10. Volkmann's contracture	3	1	1	0	0
11. Retinal artery thrombosis	1	1	0	1	0
12. Hyperhidrosis	2	1	1	0	0
Total	186	107	54	22	31

TABLE II. COMPLICATIONS OF STELLATE BLOCK

TECHNIQUE	NUMBER OF PATIENTS	NUMBER OF BLOCKS	SPINAL TAP (NO ANESTHESIA)	SPINAL ANESTHESIA	PNEUMOTHORAX	ACUTE ASTHMA	TOTAL INCIDENCE (PER CENT)
Posterior	8	8	0	1	1	0	25
Anterolateral	86	151	2	3	3	1	6
Anterior	13	27	0	0	0	0	0

the total numbers in each group are not strictly comparable, the paratracheal approach appears to be safest from the standpoint of serious complications.

Summary of Stellate Ganglion Blocks.—In the series studied, 186 stellate blocks were performed on 107 patients for the conditions and with prognostic, diagnostic, or therapeutic results as shown in Table I. Patients received from 1 to 5 blocks each, depending upon the clinical results obtained. Fourteen patients received bilateral blocks simultaneously and 16 patients received a block on the opposite side at an interval of at least twenty-four hours after the first block. The various techniques employed and their complications are shown in Table II. A transient aphonia or dysphonia noted in 3 of 27 blocks by the paratracheal approach is not included as a major complication. Alcohol was utilized in 37 of the 107 patients. Only 4 injections were judged unsuccessful, a high therapeutic efficiency regardless of technique.

The complications will be described in detail.

Complications

CASE 1.—The patient was a hypertensive 40-year-old woman who suffered repeated attacks of status asthmaticus uncontrolled by the usual medications. Five cubic centimeters of procaine were injected into both stellate ganglia using the anterolateral approach without incident. One month later, the same procedure was repeated with the same technique. Unfortunately, accidental subarachnoid injection resulted following which she was in profound shock for thirty minutes. Therapy with oxygen and vasopressors was successful. Four months after the accidental spinal anesthesia, an alcohol block of the right stellate ganglion was completed with no untoward effect.

Diagnosis.—Accidental spinal anesthesia.

CASE 2.—The patient was a 34-year-old man whose therapy for traumatic causalgia of the upper extremity was a series of stellate ganglion blocks. During the fourth block, by the anterolateral technique, he complained of dyspnea, vertigo, and then rapidly lost

consciousness. He was given artificial respiration with oxygen for twenty minutes. Blood pressure, which was 80/60, was supported by ephedrine sulfate intravenously. It was interesting that during the time of respiratory paralysis the patient could thrust his legs about. After apparent recovery, the patient was allowed to go home that evening. He returned the next day because of headache. This was followed in a few days by pneumonia which cleared with antibiotic therapy.

Diagnosis.—Accidental spinal anesthesia.

CASE 3.—A 50-year-old woman with phantom pain, following amputation of the right upper extremity, had a stellate block by the posterior approach with 8 c.c. of 2 per cent procaine. At the end of the injection, there was frank respiratory difficulty. Sensory anesthesia was noted to the fifth cervical spinal cord level on the right and the fifth thoracic spinal cord level on the left. Motor paralysis was present in the right lower and the left upper extremities. The blood pressure was 80/50. She was treated with ephedrine and oxygen. Recovery was intact except for severe headache. The phantom pain was relieved and a Horner's syndrome persisted.

Diagnosis.—Accidental spinal anesthesia.

CASE 4.—A 30-year-old woman with old rheumatic heart disease and auricular fibrillation had embolization to the left brachial artery resulting in pain, reduced skin temperature, and palsy of the left hand and forearm. A left stellate block by the anterolateral approach was performed using 18 c.c. of 1.5 per cent procaine. Five minutes after the injection, the patient suddenly became agitated and apprehensive. Respirations gradually ceased in another minute. Unconsciousness ensued, the limbs became flaccid, the pupils were widely dilated. Artificial respiration with a Kreiselman bellows resuscitator[8] was immediately instituted. Color remained good. The blood pressure, five minutes after artificial respiration was begun, was 75/50 with a pulse of 60 per minute. Twenty-five minutes after the block, the patient was put in a Drinker respirator and nasotracheal intubation was performed. Ten minutes later the patient was able to move head and eyes but spontaneous respiration was inadequate for proper ventilation. Two hours and twenty-five minutes after the block, the patient was conscious and moderately alert. At this time she did not react on the endotracheal tube but indicated that it annoyed her. The respirator was stopped and spontaneous respirations were resumed. The endotracheal tube was removed. After the patient was taken from the respirator, she complained of pain in the left arm. Flexion of the fingers, previously impossible, was executed with little difficulty. The surface temperature of the affected hand was unimproved for the next twenty-four hours, at which time it gradually increased. Forty-eight hours after the block the temperature of the hand was normal and the brachial artery could be palpated at its distal third. Eight days later the radial pulse was first noted. Recovery was uneventful.

Diagnosis.—Accidental spinal anesthesia.

CASE 5.—A 30-year-old woman with intractable asthma had a right stellate block by the anterolateral approach with 4 c.c. of 1.5 per cent procaine. After the injection, readjustment of the needle was attempted and a spinal tap was done. Except for headache, recovery was uneventful.

Diagnosis.—Accidental spinal puncture.

CASE 6.—A 51-year-old man with asthma had a right stellate block by the anterolateral approach. Insertion of the needle yielded spinal fluid. The needle was withdrawn 0.5 cm. and blood aspirated. The needle was then withdrawn another 0.5 cm. and 4 c.c. of 2 per cent procaine injected. The patient returned in a week for a left stellate block with alcohol. The patient's condition was improved.

Diagnosis.—Accidental spinal puncture.

CASE 7.—A 40-year-old man with asthma had an acute asthmatic episode immediately following the injection of the stellate ganglion with 6 c.c. of 1.5 per cent procaine followed by 2 c.c. of absolute alcohol. This was treated unsuccessfully with epinephrine. Aminophyllin intravenously terminated the attack.

Diagnosis.—Acute asthma.

CASE 8.—A right stellate ganglion block was attempted on a 31-year-old asthmatic man by the anterolateral approach. No confirmatory signs of sympathetic paralysis were noted. Radiographic chest studies revealed an asymptomatic complete pneumothorax the next day. Recovery and expansion of the lung were uneventful.

Diagnosis.—Traumatic pneumothorax.

CASE 9.—A right stellate ganglion block by the posterior approach with 15 c.c. of 1.5 per cent procaine was completed upon an elderly woman with chronic asthma. The patient became very pale and experienced difficulty in breathing, resembling an asthmatic attack, almost immediately. No Horner's syndrome was presented. X-ray examination revealed a 50 per cent collapse of the right lung.

Diagnosis.—Traumatic pneumothorax.

CASE 10.—A middle-aged woman with status asthmaticus for two weeks was treated with a right stellate ganglion block by the anterolateral approach with 15 c.c. of 1.5 per cent procaine. Evidence of Horner's syndrome developed in five minutes. Ten minutes later increasing dyspnea and cyanosis were noted. Thoracentesis yielded over 1,000 c.c. of air.

Diagnosis.—Traumatic pneumothorax.

CASE 11.—A 26-year-old woman with bronchiectasis of the right middle, right lower, and left lower lobes was hospitalized because of increasing dyspnea. A right pneumonectomy was performed when bronchospirometry showed almost no ventilation in the right lung. Three months later a left stellate block using an anterolateral approach was performed because of chronic intractable asthma. A Horner's syndrome developed almost immediately without relief of the asthma. Four hours later the patient became acutely dyspneic and suffered circulatory collapse. The diagnosis of tension pneumothorax was confirmed at once and air withdrawn from the left pleural space. The expansion of the lung was maintained by continuous suction for four days. Recovery from the pneumothorax was satisfactory. The asthma was not controlled.

Diagnosis.—Traumatic pneumothorax.

THORACIC SYMPATHETIC BLOCKS

Anatomy.—The sympathetic trunk enters the thorax in front of the neck of the first rib, medial to the superior intercostal artery and the first thoracic nerve and posterior to the apex of the pleura. It descends anteriorly to the neck of the second rib, heads of the next three ribs, on the ligament radiatum for the next three, and finally on the sides of the lower thoracic vertebrae. Thus, the trunk gradually progresses downward, medially and anteriorly. It lies behind the pleura in its entire course.

Usually there are twelve sympathetic paired ganglia but their number may be reduced by the fusion of one or more ganglia. They send gray rami posteriorly and laterally to the intercostal nerves and receive white rami.

The cervical sympathetic trunk sends fibers to supply the structures of the head and neck. The stellate ganglion and the first through the fourth thoracic ganglia are accepted as the supply to the arm; the heart and aorta are innervated by the first through the fifth thoracic ganglia. The greater splanchnic nerves arise from the fifth to ninth thoracic ganglia to supply the aorta and esophagus and send fibers to the stomach, gall bladder, liver, and pancreas. The lesser splanchnic nerves from the tenth and eleventh thoracic ganglia supply the celiac ganglion and the least splanchnic from the twelfth thoracic ganglia goes to the renal plexus.

Techniques.—

The variations in techniques in thoracic sympathetic block are few when compared to those described for the stellate ganglion. Practically all are modifications of one of the techniques described by Labat[9] differing only slightly in angle and depth of the insertion of the needle.

Labat technique: The patient lies on the opposite side to the one to be injected in the posture commonly described for the induction of spinal anesthesia. The twelfth thoracic vertebra and the spinous process of the seventh cervical vertebra are used as landmarks. Wheals are raised opposite the appropriate spinous process 4 to 5 cm. from the midline. An 8 cm. needle is directed at a 25° angle with the saggital plane passing between the ribs and transverse processes until it impinges on the body of the vertebrae just in front of the intervertebral foramen. Three to 5 c.c. of procaine or 3 c.c. of alcohol can be used for anesthesia.

White[10] used 10 cm. needles and inserted them until the rib or transverse process was contacted at a depth of 2 to 5 cm. A rubber marker was then placed 3 to 4 cm. from the skin, the needle withdrawn to subcutaneous level, and reinserted at an angle of 30 to 25° to the medial sagittal plane and perpendicular to the curvature of the back in relation to the long axis of the thorax. Contact was made at the marker and injection was completed with 2 c.c. of 1 per cent procaine followed in five to ten minutes by 5 c.c. of absolute alcohol.

Seldon,[11] in performing the technique of Labat, preferred pentothal or other general anesthesia prior to the injection of absolute alcohol rather than risk dilution of the alcohol with procaine.

The group of patients reported here were blocked by a modified Labat technique. The patients are placed in a prone position with their arms hanging over the sides of the table. A pillow is then placed under the anterior surface of the body to exaggerate the curvature of the spine. Skin wheals are raised 4 to 5 cm. from the midline opposite the appropriate spinous process and 10 cm., 24-gauge, short beveled, stiletted needles are then inserted toward the midline at an angle of 20 to 30° with the sagittal plane at right angles with the vertical axis. If the rib or transverse process is not encountered, then the needle should impinge on vertebral body at a depth of about 8 cm. If the rib or transverse process is encountered, then the needle is withdrawn to subcutaneous depth and reintroduced cephalad at an angle of approximately 30°. The needles are so directed that they will be placed on the lateral part of the vertebral body. After all the needles are placed, the stilets are withdrawn and a drop of procaine placed on each hub. Aspiration into the needle indicates that the needle is within the pleural space and readjustment is necessary. If spinal fluid or blood emerges, misplacement of the needle is obvious. The syringe is attached after all tests are negative and 3 to 4 c.c. of 1.5 per cent procaine are injected. Paresthesias and/or anesthesia are not looked for; signs of sympathetic paralysis are used as the indication of correct placement of the needles. After ten minutes, 3 to 4 c.c. of absolute alcohol are injected through each needle. Patients are usually well sedated with an opiate and a barbiturate and general anesthesia is not required. The patient remains in the hospital only long enough to recover from the sedation and until evidence of stability of the cardiovascular system is established.

Combined cervicothoracic blocks are accomplished in two fashions. The first is a combination of a posterior stellate ganglion block with appropriate thoracic segmental block. The first skin wheal is placed opposite the spinous process of the seventh cervical vertebra and the needle inserted so as to impinge on the body of the seventh cervical or first thoracic vertebrae. This technique is useful for those conditions in which alcohol is to be used for stellate and thoracic sympathetic blockade. The second technique, fashioned after Pereira,[12] depends upon the gravity diffusion of procaine caudad with the patient in the semirecumbent position. Here a stellate block is performed by a paratracheal or anterolateral approach and if, after a small test dose, a Horner's syndrome is produced, then 20 c.c. of 1.5 per cent procaine are injected. Warming of the hand and arm indicates paralysis to the first and second and sometimes third thoracic vertebrae, as well as stellate paralysis. This is a useful

technique, because of its relative simplicity and ease of performance, to use for therapy or diagnostic or prognostic block where the hand is involved. It has not been used with alcohol.

PARAVERTEBRAL THORACIC SYMPATHETIC BLOCK

Results.—Forty-two thoracic sympathetic ganglia blocks were performed on 36 patients for the conditions shown in Table III. Alcohol was used in 29 of the 36 cases (80 per cent). In 8 (27 per cent) cases of the 29 an alcohol neuritis developed. One patient developed a bleb of the skin following therapy to be described later. Complications occurred in 25 per cent of the patients treated. All blocks were successfully performed as judged by sympathetic paralysis with the exception of one patient who would not tolerate completion. This is listed as a poor result in Table III. Clinical cure did not parallel adequate denervation.

TABLE III. THORACIC SYMPATHETIC BLOCKS

DISEASES	NUMBER OF BLOCKS	NUMBER OF PATIENTS	RESULTS		
			GOOD	FAIR	POOR
Angina	28	24	16	3	5
Aneurysm (chest pain)	8	7	6	0	1
Dyspnea and hypertension	1	1	0	0	1
Herpes Zoster	1	1	1	0	0
Thrombophlebitis (arm)	1	1	1	0	0
Postmastectomy pain	2	1	1	0	0
Undiagnosed chest pain	1	1	1	0	0
Total	42	36	26	3	7

There were many occasions when a combination of stellate ganglia and thoracic sympathetic block was indicated. The experience of the combined procedure is summarized briefly in Table IV.

THORACOCERVICAL SYMPATHETIC BLOCKS

Results.—One hundred thirty thoracocervical sympathetic blocks were performed on 75 patients with the results shown in Table IV. Seventeen of the patients had complications which are listed in Table V. Alcohol was used in 50 patients, 4 of whom (8 per cent) developed annoying alcohol neuritis. One asthma patient died seven hours after the block but she was moribund when the block was performed. It was felt by all observers that the attempted therapy did not hasten the exitus. One other patient died with a pneumothorax.

The complications will be described in detail.

Complications

CASE 12.—A 51-year-old man with anginal syndrome underwent a prognostic block of the sympathetic ganglia of the first through the fifth thoracic ganglia with 1.5 per cent procaine 5 c.c. each. Upon exercise no anginal pain was elicited. Three days later the patient had the second through the fifth thoracic ganglia blocked with procaine followed by alcohol (4 c.c. each). Pain relief was excellent but the patient returned in eight days with alcohol neuritis of the segments blocked. Palliative treatment was advised and instituted with good results.

Diagnosis.—Alcohol neuritis.

TABLE IV. CERVICOTHORACIC SYMPATHETIC BLOCKS (COMBINED)

DISEASES	NUMBER OF BLOCKS	NUMBER OF PATIENTS	RESULTS		
			GOOD	FAIR	POOR
Angina	52	24	14	8	2
Asthma	32	27	8	7	12
Axillary artery spasm	1	1	1	0	0
Thrombophlebitis	3	2	2	0	0
Buerger's disease	1	1	1	0	0
Raynaud's disease	8	5	4	0	1
Frostbite	5	2	1	0	1
Bronchiogenic carcinoma with metastasis	4	2	1	1	0
Causalgia	11	6	0	5	1
Phantom pain	2	2	0	2	0
Hyperhidrosis	5	1	1	0	0
Scleroderma	3	1	1	0	0
Volkmann's contracture	3	1	0	0	1
Total	130	75	34	23	18

TABLE V. COMPLICATIONS (COMBINED CERVICOTHORACIC SYMPATHETIC BLOCK)

Alcohol neuritis	4	
Anesthesia, left ulnar, T_1 and T_2	1	
Asthmatic attack	3	
Pneumothorax	4	(1 death)
Cord penetration	1	
Hemopneumothorax	1	
Aphonia	1	
Untoward drug reaction	2	
Total	17	(23 per cent of patients; 13 per cent of blocks)

Discussion.—In the 12 (15 per cent) cases of neuritis encountered of 79 cases in which alcohol was used, the onset ranged from one to twenty-three days with practically all in the six- to eight-day period. The neuritis lasted about one to two weeks in the majority of cases. Treatment varied, depending upon the severity of the symptoms, from mild analgesics to repeated procaine blocks of the sensory nerves. Usually only one or two blocks were necessary to keep the patient comfortable.

Alcoholic neuritis is the most common complication mentioned in this form of therapy. Various figures are found in the literature ranging from 0 to 90 per cent for the incidence of neuritis, but White and Smithwick[13] found that troublesome intercostal neuritis will be found in about 10 per cent of the patients. The incidence will be reduced if the needles are placed accurately on the lateral surface of the body of the vertebra anterior to the somatic nerves. If sympathetic paralysis without sensory paralysis follows the injection of 1 to 2 c.c. of procaine, then it is probable that neuritis will not follow the injection of 3 to 4 c.c. of alcohol.

CASE 13.—A 52-year-old man with a five-year history of severe bronchial asthma was being treated with a combined posterior stellate ganglion and second and third thoracic ganglia sympathetic block with procaine. The patient suddenly became dyspneic, apprehensive, and slightly cyanotic. There were signs and symptoms of traumatic pneumothorax present. He was treated with oxygen and positive pressure and the pleural space aspirated. He was removed to the ward where water-seal drainage was instituted and the patient placed in an oxygen tent. Forty-eight hours later the needle was removed from the chest. Following one more aspiration, the patient made an uneventful recovery.

Diagnosis.—Traumatic pneumothorax.

CASE 14.—A 35-year-old woman with severe bronchial asthma was admitted for thoracic sympathectomy. An "emergency block" was requested and the right stellate and the second and third thoracic sympathetics were blocked with procaine. The patient continued

to breathe with severe embarrassment. After three to five minutes, she complained of auditory and visual disturbances. The pulse became slow at this point. She had a moderate convulsive attack and shortly thereafter respiratory efforts ceased. No pulse or heartbeat was felt. Endotracheal intubation and artificial respiration with oxygen had already been started. Epinephrine was injected directly into the heart and air was aspirated from the chest, but the patient did not recover. A post-mortem chest film showed a right pneumothorax.

Diagnosis.—Traumatic pneumothorax.

Discussion.—Pneumothorax is the most common of the major complications following thoracic sympathetic block. In 4 cases of 130 thoracic blocks, 1 ended fatally before therapy could be instituted. The pertinent anatomy of the thorax makes this a real danger. Surprisingly few instances of pneumothorax are reported in the literature but the possibility should always be considered.

CASE 15.—A 27-year-old man whose upper extremity was encased in plaster for forty hours as therapy for a fractured radius and ulna developed a Volkmann's contracture. A left stellate block was performed at once. The block was repeated two days later. Four days later it was felt that cervicothoracic sympathetic block would be more effective. The sympathetics of the first, second, and third thoracic ganglia were injected with 1.5 per cent procaine. The patient complained of pain in the chest immediately following the block but examination failed to show any pneumothorax. However, the next day dyspnea and tachycardia were evident. An x-ray examination showed a fluid level to the eighth thoracic vertebra and complete collapse of the left lung. Aspiration of the chest yielded 1,500 c.c. of blood. Some air was allowed to remain in the chest and a transfusion of 500 c.c. whole blood was given. After a stormy course, the patient recovered but the left upper lobe remained collapsed until a decortication was done.

Diagnosis.—Traumatic hemopneumothorax.

Discussion.—This is an unusual course of events not previously reported. It was believed that in the collapse of the lung small veins at the apex between the visceral and parietal pleura were torn resulting in hemorrhage.

CASE 16.—A 55-year-old man with a four-year history of bronchial asthma had a block of the right stellate ganglion and the sympathetics of the second and third thoracic ganglia with procaine and absolute alcohol. A Horner's syndrome developed immediately following the block but was absent eighteen hours later. The patient was not relieved of the asthma. One month later the patient returned for a left stellate block which was done with procaine, 1.5 per cent. No alcohol was injected because the block immediately precipitated a severe attack of asthma lasting fifteen minutes. Since the patient was practically free of attacks with adrenalin in oil, no further therapy was attempted.

Diagnosis.—Acute asthma.

Discussion.—The three asthmatic attacks precipitated by this form of therapy make it obligatory to perform all blocks with procaine before permanent sympatholysis is attempted with alcohol or surgery. The mechanism, rationale, and results of sympatholysis in patients with asthma has been reviewed by Miscall and Rovenstine.[14]

CASE 17.—A 43-year-old woman with syphilitic aortic aneurysm and the anginal syndrome first came to the clinic in November, 1939. She had a left stellate ganglion block with 5 c.c. of 1.5 per cent procaine and 1 c.c. of absolute alcohol. Attacks were less frequent and less severe. Two weeks later the procedure was repeated and six days later the second to the fifth thoracic sympathetic ganglia on the left side were blocked with procaine and absolute alcohol. The pain was relieved and the patient returned to the clinic in October, 1940 (one year later) for a repetition of the procedure. Ten months later, in June, 1941, she was blocked successfully again. In May, 1942, the patient returned with anginal pain and the left stellate and upper thoracic sympathetic ganglia were blocked with absolute alcohol. Five days later the patient was free of pain but exhibited anesthesia of the ulnar nerve and the first and second thoracic segments.

Discussion.—This case presents many interesting points. Anesthesia of a segment about the nipple is more frequent than is reported since many patients and physicians do not consider "the frozen area" important. The anesthesia carries little consequence if it does not involve the upper limb. It probably arises from the destruction of the sensory fibers by the alcohol and is related to the neuritis which occurs with incomplete destruction.

The regeneration of nerve fibers is well illustrated here. It is difficult to promise a patient more than six months to one year relief since sympathetic fibers can regenerate.[15]

CASE 18.—A 32-year-old man who developed hyperhidrosis totalis six months following a skull fracture was treated with right stellate ganglion block as a preliminary procedure. Two days later, while a left stellate ganglion block was being attempted, the dura was pierced and severe pain ensued. Anesthesia was noted on the left down to the umbilicus though no procaine was injected. The next day no residual anesthesia was noted and the patient went on to have the right stellate and second and third thoracic ganglia injected with procaine and alcohol.

Diagnosis.—Spinal cord penetration.

Discussion.—No serious consequences ensued from this case, but Molitch and Wilson[16] reported a vivid description of Brown-Séquard paralysis following therapy for angina pectoris.

CASE 19.—A 60-year-old man with angina pectoris had a block of the second to the fifth thoracic ganglia with procaine and absolute alcohol which gave relief of substernal but not precordial pain. He returned in two weeks with a history of a blister of three days' duration. This was located on the left side of the back about 6 cm. from the midline and over the fifth to the ninth ribs. There was hypoalgesia of the second to the ninth thoracic ganglia. Aspiration revealed a clear amber fluid.

Diagnosis.—Skin bleb.

Discussion.—Whether this is related to the block, skin preparation, or hypoalgesia cannot be said. Nothing like it has been reported to our knowledge.

CASE 20.—A 54-year-old man with angina pectoris having a diagnostic left stellate ganglion block developed severe bradycardia and cyanosis following the skin wheal and the introduction of the needle while in a sitting position. This cleared upon being placed in the prone position.

Diagnosis.—Drug reaction.

CASE 21.—A 44-year-old man with asthma had jerky convulsive movements with cyanosis following attempted procaine injection of the first, second, and third thoracic ganglia.

Diagnosis.—Drug reaction.

Discussion.—Whether these are true allergic reactions rather than psychosomatic affairs is difficult to say. Procaine reactions have been adequately described, but both these patients had subsequent uneventful thoracic sympathetic blocks with procaine and alcohol.

Comment.—Several striking features have become evident as a result of this survey of stellate ganglion and upper thoracic sympathetic blocks. Regardless of the technique utilized, successful denervation with procaine is easily attained. The therapeutic results in so far as patient care is concerned depend more upon intelligent choice of stellate or thoracic sympathetic block and less upon the technical skill of the anesthetist. This statement is obviously not pertinent in those instances where diagnosis or prognosis was the goal. In general, it appeared that blocks performed posteriorly or from the lateral aspect carried a higher potentiality of risk than those performed anteriorly. The major complications are pneumothorax and spinal anesthesia, although others have been observed. These are most important since they are most common and potentially fatal.

SUMMARY

1. The experience gained in 358 nerve blocks of the stellate and upper thoracic sympathetic ganglia upon 218 patients is presented.

2. Successful denervation is easily accomplished but at a risk of significant undesirable sequelae (5.9 per cent of the number of blocks).

3. Brief descriptions of 21 cases are employed to document the nature of the complications.

4. Traumatic pneumothorax, accidental spinal anesthesia, and alcohol neuritis are the most common untoward events.

5. The incidence of these complications is higher in posterior or lateral approaches to the sympathetic chain. The safest method for the cervical sympathetic is a paratracheal technique when possible.

6. Stellate ganglion and thoracic sympathetic block should be employed without hesitancy when properly indicated. However, since the procedures are not without considerable danger, adequate precautions must be observed to minimize the development of the complications noted in this study.

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CILIATED EPITHELIAL CYST OF THE ESOPHAGUS

Report of a Case

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CILIATED epithelial cysts of the mediastinum have been reported with increasing frequency within recent years and several reviews have described their clinical and pathologic features.[1, 2, 3, 4] The occurrence of these lesions in the esophageal wall, however, is relatively uncommon. The cysts are con-

Fig. 1.—Preoperative film of esophagus with barium. A mass arises from the right lateral wall of the esophagus.

genital and generally thought to arise from a bud or diverticulum of the primitive foregut. Other theories assume the imperfect closure of a tracheoesophageal fistula or the isolation of one of the vacuoles normally present in the embryonic esophagus. Ranstrom[5] collected twenty such cases reported prior to 1946, and described two from his clinic. The majority of these patients were newborn

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infants in whom the diagnosis was made at autopsy. We have found but two cases in which ciliated epithelial cysts of the esophagus were removed surgically.[3, 6]

We have recently treated a young woman who presented the clinical features of a benign tumor of the esophagus. Pathologic study of the mass excised from the esophageal wall revealed that it was a ciliated epithelial cyst.

CASE REPORT

K. B., a 22-year-old white married woman, was admitted to the Tumor Service of the United States Marine Hospital on Dec. 13, 1949. She complained of difficulty in swallowing of four weeks' duration. Past history and family history were not relevant to the present illness.

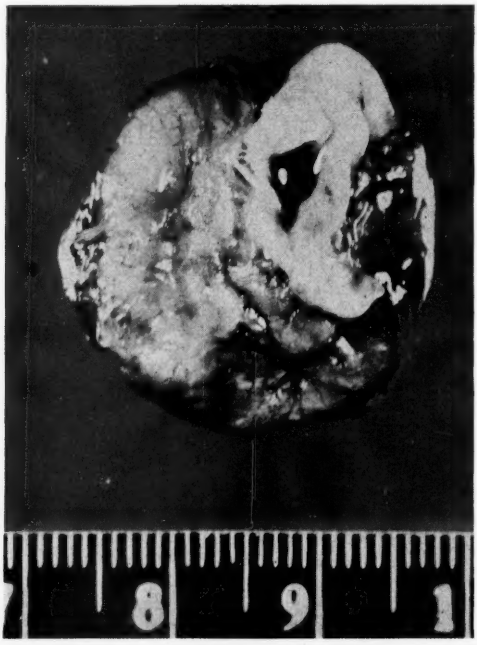

Fig. 2.—Ciliated epithelial cyst excised from the wall of the esophagus (cm. scale).

Present illness was dated from one month prior to admission when the patient first noted slight difficulty in swallowing solid foods. This dysphagia progressed and for one week before admission even liquids were swallowed with difficulty. The act of swallowing was accompanied by moderately severe substernal and epigastric pain. There had been no vomiting or regurgitation.

Physical findings were entirely within normal limits. The chest was clear to percussion and auscultation. There were no enlarged peripheral lymph nodes.

Laboratory examinations of blood and urine revealed no abnormalities.

X-ray examination of the chest was considered normal. Fluoroscopic and radiographic examinations of the esophagus with barium revealed a filling defect in the middle third of the esophagus (Fig. 1). A mass appeared to arise from the right anterior wall of the

esophagus and protrude into its lumen. When large amounts of barium were swallowed the mass was displaced and permitted free passage of the meal. The radiologist believed that the mass was an intramural, extramucosal tumor of the esophagus, probably benign.

Esophagoscopy revealed the esophagus to be normal except for an area 28 cm. from the upper dental arch. Here there was bulging of the right lateral wall into the lumen but the mucosa was intact and the instrument was passed to the cardia with ease. A preoperative diagnosis of leiomyoma of the esophagus was made.

Fig. 3.—Photomicrograph, ×430, of inner fibrous portion of the cyst wall showing a lining of pseudostratified ciliated columnar epithelium.

Exploratory thoracotomy was carried out on Dec. 15, 1949. The patient was anesthetized with endotracheal nitrous oxide, oxygen, and ether, and a right posterolateral incision made. The seventh rib was resected and the right pleural space entered through its bed. The right lung was normal. In the posterior mediastinum, just below and posterior to the right main bronchus, was a cystic mass 5 cm. in diameter. The mass was intimately attached to the right anterior wall of the esophagus and the muscular coats of the esophagus expanded over the mass and lost themselves upon its surface. The mass was excised from the esophageal

wall by blunt and sharp dissection. During the dissection the cyst ruptured and several drops of gray, viscid fluid oozed from the opening in its wall. The lumen of the esophagus was not entered. The muscular coats of the esophagus were approximated over the defect with interrupted sutures. The mediastinal pleura was not closed. Prior to closure of the chest a mushroom catheter was introduced through a stab wound in the fifth intercostal space.

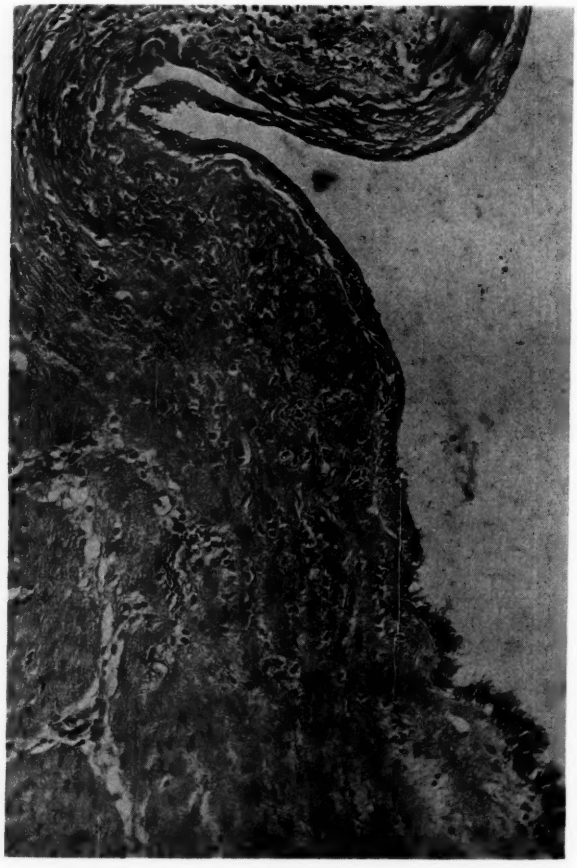

Fig. 4.—Photomicrograph, ×190, of inner portion of the cyst wall which shows a lining, on the right, of pseudostratified ciliated columnar epithelium and on the left a thin layer of stratified, relatively flat cells.

Postoperatively the catheter was connected to underwater drainage. Chest roentgenograms revealed complete expansion of the lung and the catheter was removed on the second postoperative day. The patient was given a liquid diet immediately after operation and a soft diet on the fifth day. Postoperative roentgenograms of the esophagus showed no abnormality. The patient was discharged on the thirteenth day after operation. She is well and symptom free three months after operation.

Gross Pathologic Examination.—The cysts measured 3 by 4 cm. after rupture (Fig. 2). Sectioning revealed that it contained gray gelatinous fluid. The wall was 5 mm. in thickness.

The lining of the cyst was corrugated and simulated the mucosa of small intestine. Blocks from the cyst wall were submitted for microscopic examination.

*Microscopic Examination**.—The inner portion of the cyst wall is formed of dense, sparsely cellular fibrous tissue which is hyalinized in some areas. This layer blends in an irregular fashion with the surrounding lamina of smooth muscle. In the inner fibrous portion of the wall there are scattered collections of foamy macrophages and occasional foci of lymphocytes and neutrophils. In the areas where these changes are most prominent the cyst is devoid of an epithelial lining. Elsewhere there is a lining of either pseudostratified ciliated columnar epithelium or a very thin stratified layer of relatively flat cells (Figs. 3 and 4). This latter type of epithelium is seen infrequently and in small areas. Diagnosis was ciliated epithelial cyst of the esophagus.

SUMMARY

A case of ciliated epithelial cyst of the middle one-third of the esophagus is described. The cyst caused partial obstruction of the esophagus which was relieved by transthoracic excision of the lesion.

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SURGICAL CORRECTION OF A DOUBLE AORTIC ARCH

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GREAT strides have been made recently in the diagnosis and surgical treatment of cardiovascular anomalies. For greater accuracy in diagnosis the radiograph and stethoscope have been supplemented by angiocardiography and cardiac catheterization. As a result many anomalies that formerly were case reports based upon autopsy material are now diagnosed in time for surgical correction. This report is an example of a congenital vascular ring correctly diagnosed and properly treated by ligation and division of the offending primitive arch.

In 1737, Hammel first described a case of double aortic arch and since that time over forty cases have been reported in the literature. Recently Gross and Ware, and Sweet reported four cases successfully diagnosed and operated upon with subsequent relief of the symptoms of constriction.

Embryologically a double aortic arch is the result of the persistence of both fourth branchial arches, and the fusion of the arches with the dorsal aortas to form the descending aorta. The resulting anomaly constitutes a vascular ring. The most common anatomic pattern consists of a large right aortic arch which passes to the right of the esophagus and trachea in a posterior direction, then turns to the left behind the esophagus and trachea and joins the smaller left aortic arch. On the other hand, the left aortic arch passes anterior to the esophagus and trachea and then posteriorly to join the right aortic arch. The continuation becomes the descending aorta.

In 1939, the symptomatology was nicely described by Wolman. These infants have noisy, stridorous respirations, usually noted promptly after birth, but not always. Feedings may be slow and accompanied with respiratory embarrassment in the form of dyspnea and cyanosis. In addition episodes of respiratory infection are common. Any one or all of these symptoms should suggest to the examiner the possible existence of a constricting ring.

Newhauser presented carefully studied roentgenologic findings of four cases from The Children's Hospital in Boston. He believed that there may be no abnormality on the straight posteroanterior film but in the lateral view there is narrowing and anterior displacement of the trachea at the level of the aortic arch. If the esophagus is filled with barium there appears a rounded pulsating mass posterior to the esophagus which, of course is the posterior right aortic arch displacing the esophagus forward. At the same time in the posteroanterior film the esophagus is visibly narrowed from both right and left sides due to the pressure of the vascular ring. Further if Lipiodol is instilled into the trachea it also may be narrowed in the posteroanterior diameter.

Griswold and Young have said that when a double aortic arch causes symptoms of constriction, these symptoms will develop during the first two years of

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life. Furthermore, the mere diagnosis of double aortic arch is not an indication for operative intervention. Symptoms should be present before surgery is considered.

The proper treatment is surgical division of one of the arches—thus relieving the constriction. The anterior arch is more accessible surgically and is usually smaller, but before ligation of either arch the anatomy of the vascular pattern must be carefully understood.

Fig. 1.—Preoperative barium swallow showing bilateral indentation of the esophagus at the level of the aortic arch. Note the dilated distal esophagus and stomach.

CASE REPORT

J. U., a 14-month-old female infant, was admitted to the Syracuse Memorial Hospital July 28, 1949, because since birth this child had had choking episodes, and difficulty in breathing associated with the feedings. Respirations were noisy and wheezy, especially when sleeping or crying. During these spells the child became blue and on occasions respirations apparently ceased. The parents kept oxygen at home for such emergencies and the assistance of the police or hospital resuscitator had been called for on several occasions. Three months before admission, while in Florida, subsequent to a severe episode, she was treated for bronchopneumonia. Three weeks before admission she was resuscitated in the emergency room of another hospital and again a diagnosis of aspiration pneumonia was made. At this admission a vascular ring was considered as a possible etiological factor by the attending pediatricians (Drs. M. P. and C. N.).

The baby had a twin and the sister was four pounds heavier and one-half inch taller. The mother stated that the other twin developed skills several weeks sooner than the patient.

Physical examination revealed a well-developed and nourished 14-month-old white female infant. She was alert and cooperative. Wheezing respirations were present and these became accentuated when the infant cried. The rest of the examination was negative.

Bronchoscopy was done on July 13, 1949, by Dr. L. S. who described a reddened trachea with definite narrowing of trachea in the anteroposterior diameter, just above the carina. Abnormal pulsations also were noted in this region.

A barium study was made of the esophagus on July 20, 1949, by Dr. C. H. Radiographic and fluoroscopic examination of the chest and esophagus showed that there was definite narrowing of the esophagus at the level of the aortic arch. The narrowing was bilateral, and the defect was typical of a congenital aortic ring. The nature of the deformity of the esophagus suggested that the vascular anomaly was a double aortic arch. The distal esophagus was dilated as was the stomach (Fig. 1).

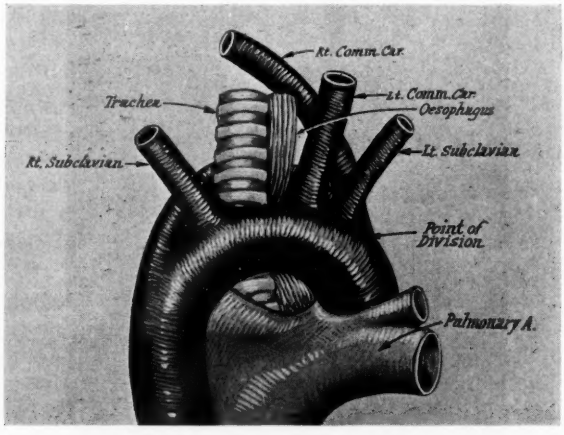

Fig. 2.—Sketch of the anatomy as found at operation.

Conclusion was that the examination of the esophagus showed definite deformity due to a vascular ring. The vascular anomaly was probably a double aortic arch. The cardiac shadow was normal. There was no evidence of disease in the lungs.

Exploratory thoracotomy was performed on Aug. 1, 1949.

Patient was given rectal anesthesia and intratracheal general anesthesia. Blood was started immediately in the right ankle. Patient was placed on her right side, and the left chest was prepared and draped in the usual manner for a thoracic operation. Usual posterolateral incision was made in the left fifth intercostal interspace. The fourth and fifth ribs were fractured at their posterior attachment. A rib-spreader was introduced. The pleura on the left lateral surface of the superior mediastinum was opened, and dissection was begun above the aortic arch. The left common carotid and left subclavian arteries were isolated, and tapes were placed around them for traction. The arch of the aorta was completely exposed and an anomalous blood vessel was found to arise from the ascending aorta. This vessel was isolated by further dissection and was found to have one branch which went cephalad and was thought to be the right subclavian artery. Another branch went around the esophagus and trachea and reunited with the arch of the aorta to the left of the esophagus. This vessel formed a complete vascular ring about the esophagus and trachea.

Caudad to this vascular ring, the esophagus was bulbous and dilated. Posterior to the esophagus and the trachea, this anomalous vessel was closely adherent to these structures. A large artery arose from the posterior arch to the left of the esophagus and passed obliquely to the right. It was considered to be the right common carotid artery. Finally, it was decided that it would be easier to transect the vascular ring anteriorly for technical reasons, since the exposure posteriorly would be difficult to obtain (Fig. 2).

The anterior arch of the aorta was temporarily clamped at a point just proximal to the common aorta. The circulation to all carotid and subclavian vessels remained good. Therefore it was decided to transect the arch of the aorta anteriorly. The anterior arch, just in front of the esophagus, was then doubly ligated with No. 3 silk, and divided. Subsequent to the division the ends spread laterally for a distance of 4 cm., and both the trachea and esophagus moved forward. Therefore, it was felt that the vascular ring, which had constricted the esophagus, was definitely released.

Fig. 3.—Postoperative barium swallow.

The pleural cavity was then irrigated and hemostasis checked. The superior mediastinum was not repleuralized. The thorax was then closed in anatomic layers. A rubber tube was placed low in the pleural cavity, (connected to a "water seal" for drainage) to maintain re-expansion of the lung. The patient tolerated the procedure very well. She received 350 c.c. of blood on the table and was returned to her room in good condition. The postoperative course was uneventful. Some stridor was present for several days, which was considered to be laryngeal edema due to the endotracheal tube. The child was discharged on the eighth postoperative day in good condition. Since discharge from the hospital she has gained weight and is now the same size as the twin sister. The mother states that she can no longer tell which twin is crying. Feedings are normal and uneventful.

On Jan. 11, 1950, a repeat barium swallow was reported. Complete radiographic and fluoroscopic examination of the chest revealed the heart to be of normal size, shape, and position. The lung fields were clear. There was no evidence of active pulmonary disease.

The fifth and sixth ribs on the left posteriorly showed moderate callous formation following fracture due to a thoracotomy. The barium passed freely through the esophagus into the stomach. There was no evidence of constriction or deviation. There was the normal concave marking that we see at the level of the aorta. The lumen was of normal caliber throughout. There was no posterior defect on the esophagus as one sees when there is a double aortic arch or a right aortic arch. The stomach was filled with air, but was of normal size for a patient of this age (Fig. 3).

Conclusion was that the heart and lung fields were normal. The esophagus was of normal caliber throughout, and there was no evidence of stricture or defect around the region of the previous surgery.

SUMMARY

A case of double aortic arch is presented which was correctly diagnosed and successfully treated by operation. The diagnosis is suggested from the history and physical findings, and is easily confirmed by bronchoscopic and roentgenologic studies. The only treatment is surgical correction by division of one arch.

I should like to express my appreciation to Dr. J. W. Chamberlain and Dr. William Michaels for valuable help given.

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THE BLOOD FLOW THROUGH AN ATELECTATIC LUNG

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AS SOON as an atelectasis has developed, the blood flow through this area is considerably decreased. During the first days and weeks this decrease in blood flow through an atelectatic part has been estimated to be about 50 per cent of the normal (Moore, 1931, and Berggren, 1942). With the aging of the atelectasis there will be a continued decrease in flow until practically no blood at all is passing the atelectatic parts.

In an acute atelectasis all venous blood from the nonventilated parts of the lung is mixed with fully oxygenated blood, thus reducing the oxygen content of the arterial blood. The arterial oxygen deficit, which is most pronounced in the acute atelectasis, will diminish at the same rate as the blood flow through the atelectatic part decreases.

The decreased blood flow in the atelectatic part of the lung might be produced by contraction of the large branches of the pulmonary artery or by collapsed capillaries around the empty alveoli. Some clinical findings speak in favor of the latter possibility. In three cases with a total tuberculous stenosis of one main bronchus, a thoracoplasty had been performed one, two, and four years previously. No arterial oxygen deficit was found with the lung breathing air or 100 per cent oxygen. When the pneumonectomy was performed the pulmonary artery to the atelectatic lung was found to be larger than expected and nearly of normal size. Furthermore, it is well known that the capillaries close down in a resting part of an organ.

EXPERIMENTAL FINDINGS

Some experiments were performed to produce atelectasis in the dog. The blood flow through the atelectatic part of the lungs was demonstrated by angiocardiography and the arterial oxygen deficit was determined.

Acute Atelectasis

During intravenous narcotal anesthesia acute atelectasis of the right lung of a dog weighing 13 kilograms was produced with the aid of a Carlens double-lumen catheter for bronchospirometry. Each lung was then breathing separately. While the left lung was breathing ordinary air, the right was first breathing 100 per cent oxygen and was then connected to a valve only permitting the outflow of gas, but no inflow.

The development of the atelectasis was followed by x-ray investigation at fifteen-minute intervals. After two hours the x-ray picture showed a pronounced atelectasis of the right lung with mediastinal shift and the right border of the heart only 1 cm. from the right chest wall. Still the right lower lobe was

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air-containing. With this partial atelectasis of approximately one-half of the right lung the arterial oxygen content was investigated (according to Van Slyke and Neil): there was partial atelectasis of the right lung; the left lung breathing air equaled 89.5 per cent arterial oxygen saturation; the left lung breathing 100 per cent oxygen equaled 95.9 per cent arterial oxygen saturation.

Then a complete atelectasis of the right lung was obtained by applying continuous strong suction (with a vacuum cleaner) to the right tube of the double-lumen catheter. The roentgenogram showed a total atelectasis of the right lung with the right border of the heart out at the right chest wall (see Fig. 1).

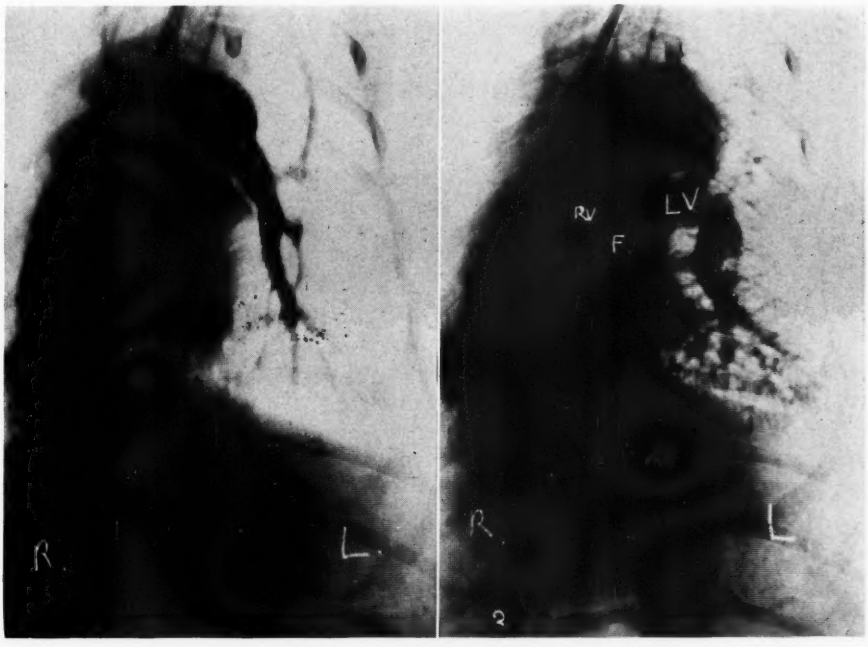
Fig. 1.—Total acute atelectasis of the right lung.

A heart catheter was now introduced through the right external jugular vein, through the right side of the heart out into the pulmonary artery. Angiocardiography was then performed by injection of 40 ml. 70 per cent Diodrast with an over-pressure syringe (according to Jönsson). Six x-ray films were automatically exposed at intervals of one second. Simultaneous exposures in right angle planes were not taken in order to avoid the disturbance of secondary radiation.

The angiocardiography showed approximately the same size of the peripheral branches of the pulmonary arteries on both sides (see Fig. 2, *A*). Some seconds later one of the left pulmonary veins (*LV*) was clearly visible at the same time as one right upper pulmonary vein (*RV*) emptied into the left auricle (*F*) (see Fig. 2, *B*). The amount of contrast in the periphery of the right atelectatic lung seemed to be greater than in the left lung.

Conclusion.—In an acute atelectasis the pulmonary arteries do not get smaller and the capillary bed remains open as indicated by the contrast filling of pulmonary arteries and veins simultaneously on both sides. The contrast filling of the periphery of the atelectatic lung is at least as pronounced as on the other side.

The arterial oxygen content during total acute atelectasis of the right lung was investigated: there was total atelectasis of the right lung; the left lung breathing 100 per cent oxygen equaled 88.0 per cent arterial oxygen saturation, 36.2 volumes per cent carbon dioxide.



A. *B.*

Fig. 2.—*A*, Angiocardiography shows the same size of the peripheral pulmonary artery branches during acute atelectasis of the right lung as compared with the ones of the distended left lung.

B, Both left (*LV*) and parts of the right pulmonary veins (*RV*) are filled with contrast medium, emptying into the left auricle (*F*). The contrast filling of the periphery of the atelectatic right lung seems somewhat more pronounced than on the left side.

To see the influence of the atelectasis on the flow of blood through nonventilated parts of the lungs, the following experiment was performed:

The right lung was again freely ventilated when the atelectasis completely disappeared. The roentgenogram showed the heart in the normal position, the trachea in the middle, and an air-containing right lung. Then the right lung was made to breathe 100 per cent nitrogen for fifteen minutes when the arterial oxygen content was investigated: the right lung breathing 100 per cent nitrogen; the left lung breathing 100 per cent oxygen equaled 85.9 per cent arterial oxygen saturation, 36.3 volumes per cent carbon dioxide.

Conclusion.—The loss of oxygen from the blood in the lung breathing 100 per cent nitrogen can be considered compensated by the other lung. An approximately equal arterial oxygen deficit is found with complete atelectasis of one lung as compared with the same lung breathing 100 per cent nitrogen. This indicates that the decrease of blood flow due to an acute atelectasis is of the same order as that due to the increased resistance in the capillary bed of a lung breathing 100 per cent nitrogen. Still a considerable amount of blood is passing through the nonventilated area in the acute stage of an atelectasis.

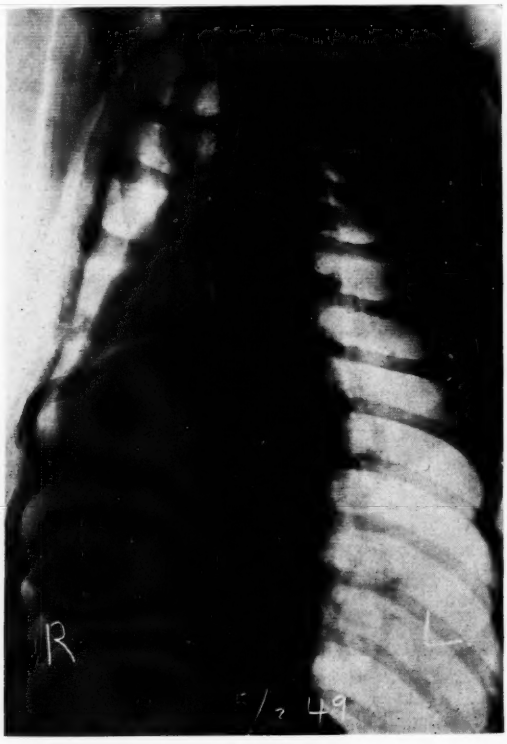


Fig. 3.—Total atelectasis of the right lung with mediastinal shift and a remaining pneumothorax.

Chronic Atelectasis

Chronic atelectasis was produced by ligation of all bronchi to the right lung. After a premedication of 1 cg. of morphine with scopolamine the anesthesia was induced with narcotal intravenously on a dog weighing 22 kilograms. An intratracheal tube was then introduced and positive pressure anesthesia continued with ether and oxygen using the spiro-pulsator. The right chest was opened after resection of most of the fourth and the posterior part of the fifth ribs. The azygos vein was divided between ligatures and trachea with the right

main bronchi was dissected free. The right upper lobe bronchus was found to leave the right main bronchus at the same level as the carina and had to be ligated separately. Then the main bronchus to the rest of the right lung could be isolated and tied with a thick ligature (boot-laces were used to prevent cutting through). The wound was closed and air aspirated from the right chest.

Fig. 4.—Lateral angiocardiography shows right (*RP*) and left pulmonary artery (*LP*) to be of the same size after total atelectasis of the right lung for twenty-four hours. *LV* is the left pulmonary vein.

Twenty-four-hour Atelectasis.—The day after the operation the dog was in good condition and running around. Roentgenogram showed a total atelectasis of the right lung with mediastinal shift to the right. There was a remaining pneumothorax on the operated side but no compression from exudate (see Fig. 3). All arterial samples for analyses were taken under intravenous narcotal anesthesia and after insertion of an intratracheal tube. The first sample was taken when the dog was breathing air. The second sample was taken when the dog had been breathing 100 per cent oxygen for fifteen minutes. The connection to the intratracheal tube was fitted with an expiratory valve permitting the expiratory air to escape. Blood gas analyses were performed according to the Van Slyke and Neill manometric method with double determinations of the oxygen content as well as of the oxygen capacity of each sample. Blood analysis

after twenty-four-hour atelectasis showed: lung breathing air equaled 81.0 per cent arterial oxygen saturation, 36.7 volumes per cent carbon dioxide; lung breathing 100 per cent oxygen equaled 93.6 per cent arterial oxygen saturation, 37.2 volumes per cent carbon dioxide.

Angiocardiography with a ventrodorsal x-ray direction was performed according to Robb-Steinberg, with injection of 40 ml. 80 per cent Umbradil in a hind-leg vein. The vessels in the atelectatic right lung could not be seen due to the contrast medium filling of the heart.

Another angiocardiography was now performed using the same Robb-Steinberg technique injecting 40 ml. 80 per cent Umbradil, but with the dog in a slightly rotated lateral position. The main right pulmonary artery (*RP*) to the atelectatic lung was found to be of the same size as the left pulmonary artery (*LP*). The lower left pulmonary vein (*LV*) was also visible (see Fig. 4).

Three-day Atelectasis.—After three-day total atelectasis of the right lung, x-ray investigation showed an increased distention of the left lung (see Fig. 5). Blood analysis showed: lung breathing air equaled 76.5 per cent arterial oxygen saturation, 41.4 volumes per cent carbon dioxide; lung breathing 100 per cent oxygen equaled 97.1 per cent arterial oxygen saturation, 43.1 volumes per cent carbon dioxide.

Angiocardiography showed the same picture as Fig. 4, with the same size of the right and left pulmonary artery.

Six-day Atelectasis.—After six-day total atelectasis of the right lung, blood analysis showed: lung breathing air equaled 83.0 per cent arterial oxygen saturation, 45.7 volumes per cent carbon dioxide; lung breathing 100 per cent oxygen equaled 94.8 per cent arterial oxygen saturation, 38.0 volumes per cent carbon dioxide.

Twelve-day Atelectasis.—Blood analysis showed: lung breathing 100 per cent oxygen equaled 92.4 per cent arterial oxygen saturation, 44.6 volumes per cent carbon dioxide.

Twenty-four-day Atelectasis.—Blood analysis showed: lung breathing 100 per cent oxygen equaled 100.5 per cent arterial oxygen saturation. No arterial oxygen deficit remained, lung breathing 100 per cent oxygen.

One-month Atelectasis.—Angiocardiography showed the same picture as in Fig. 4, with the same size of the right and left pulmonary artery.

Eight-month Atelectasis.—Blood analysis showed: lung breathing air equaled 66.8 per cent arterial oxygen saturation; lung breathing 100 per cent oxygen equaled 97.3 per cent arterial oxygen saturation.

Angiocardiography was performed through a heart catheter inserted through the left external jugular vein into the pulmonary artery; 50 ml. 70 per cent Umbradil were injected with an over-pressure syringe. With the dog in a slightly rotated lateral position, a considerable decrease in the size of the right main pulmonary artery was demonstrated (see Fig. 6, *A*). On the x-ray picture the diameter of the main right pulmonary artery measured 9 mm., as

compared with a diameter of 15 mm. of the left pulmonary artery. The corresponding diameters were equal or 15 mm. on both sides after one-month atelectasis.

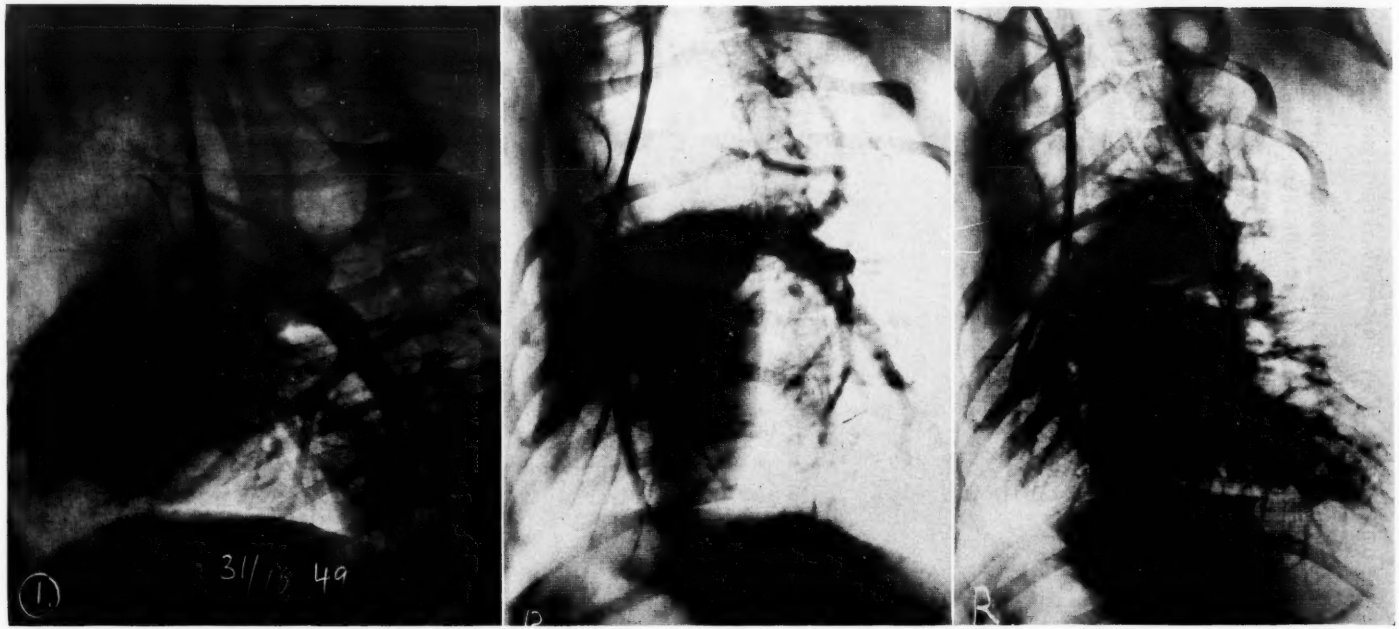
Another angiocardiography was then performed with a dorsoventral direction of the roentgenograms, but otherwise with the same technique. The right pulmonary artery was found to have decreased in size when compared with the left pulmonary artery (see Fig. 6, *B*).

Fig. 5.—Roentgenogram after total atelectasis of the right lung for three days.

One second later the contrast medium has passed through the left pulmonary artery and is filling the left pulmonary veins. At the same time on the right side the right pulmonary artery is still filled with contrast, but no contrast medium is visible in the right pulmonary veins (see Fig. 6, *C*).

Autopsy was then performed showing a complete obstruction of all bronchi to the total atelectatic right lung. All pulmonary arteries and veins had a macroscopically normal appearance. Microscopic investigation showed atelectasis of the right lung with no signs of fibrosis.

In two cases of bronchial occlusion with atelectasis of the right upper lobe due to bronchiogenic carcinoma the following values were found. Atelectasis



A. *B.* *C.*

Fig. 6.—*A*, Lateral angiocardiography showing that the diameter of the right main pulmonary artery after eight-month total atelectasis of the right lung has diminished to about 60 per cent of the size of the left pulmonary artery.

B and *C*, Frontal angiocardiography with one second's interval. *B* shows contrast in the pulmonary arteries on both sides. In *C* the contrast has passed the left pulmonary artery and is visible in the left pulmonary veins. At the same time the right pulmonary artery is still filled with contrast. No contrast is visible in the right pulmonary veins.

of right upper lobe for more than six weeks: breathing air equaled 88.5 per cent arterial oxygen saturation; breathing 100 per cent oxygen equaled 98.8 per cent arterial oxygen saturation. Atelectasis of right upper lobe for about two weeks: breathing air equaled 91.4 per cent arterial oxygen saturation; breathing 100 per cent oxygen equaled 95.2 per cent arterial oxygen saturation.

Conclusion.—In chronic atelectasis the blood flow through the nonventilated areas of the lungs diminishes with the age of the atelectasis. At the same time the arterial oxygen deficit diminishes with the lung breathing 100 per cent oxygen. No arterial oxygen deficit remained after total atelectasis of the right lung of a dog for twenty-four days. In one case of bronchiogenic carcinoma with right upper lobe atelectasis for two weeks an arterial oxygen deficit remained. In a similar case of more than six weeks' duration, there was practically no arterial oxygen deficit with the lung breathing 100 per cent oxygen.

During the first month of an atelectasis the arterial oxygen deficit is greatly diminished or disappearing. The blood flow through the nonventilated parts is diminishing at the same rate. When the greatest change in the blood flow through the atelectasis is to be found, the corresponding artery has not at all diminished in size.

After eight-month atelectasis the corresponding pulmonary artery had diminished in size, but still its diameter was 60 per cent of the contralateral pulmonary artery. The contrast medium in the artery of the atelectatic lung did not empty at the same time as on the other side, and no pulmonary veins were filled.

The blood flow through atelectatic parts of the lungs is therefore thought to be shut off in the capillaries. The large branches of the pulmonary artery are filled with slowly circulating blood, which passes either not at all or extremely slowly through the capillary bed of the atelectatic area.

SUMMARY

In an acute atelectasis the pulmonary arteries do not become smaller, and the capillary bed remains open as indicated by contrast medium simultaneously filling pulmonary arteries and veins on both sides. The contrast filling of the periphery of the atelectatic lung is at least as pronounced as on the other side. An approximately equal arterial oxygenation deficit with complete atelectasis of one lung as compared with the same lung breathing 100 per cent nitrogen is found. This indicates that the decrease of blood flow due to an acute atelectasis is of the same order as that due to the increased resistance in the capillary bed of a lung breathing 100 per cent nitrogen. Still a considerable amount of blood is passing through the nonventilated area in the acute stage of an atelectasis.

The blood flow through an atelectatic area is continuously decreasing during the first month, until practically no blood is passing through the nonventilated part of the lungs. At the same time there is no decrease in size of the main branches of the corresponding pulmonary artery. Therefore, the blood flow is thought to be shut off in the capillary bed, which is gradually closing down.

In a long-standing atelectasis the pulmonary artery will decrease somewhat in size. The contrast medium does not disappear from the artery in the atelectatic part in the same time as on the healthy side, nor are the pulmonary veins filled with contrast medium in the atelectatic part at the same time as on the healthy side. The blood, therefore, is considered to fill out the arteries of the atelectatic lung but to pass either not at all or extremely slowly through the capillary bed. The capillaries are considered to be closed down in the same way as in a resting part of an organ.

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WOUND HEALING FOLLOWING LIMITED RESECTION OF THE PARIETAL PLEURA

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THE surgical removal of pleural membranes that limit pulmonary expansion was popularized during World War II as appropriate treatment for sterile and contaminated fibrothoraces following pleural injury.[3, 7] The procedure was applied subsequently to visceral pleura thickened by tuberculosis.[1, 2] Sarot has reported extrapleural total or partial resections of the lung with simultaneous removal of affected visceral and parietal pleura for pulmonary and pleural tuberculosis.[4, 5] Tchertkoff and Selikoff noted fewer complications after extrapleural pneumonectomy than after transpleural removal of the lung.[6]

With increasing interest in the role of the pleura in intrathoracic surgery as well as the healing processes of the endothorax following pleural denudation, the following study was performed to determine tissue repair after limited pleural resections.

METHOD

Under intratracheal ether anesthesia, thoracotomies were performed on adult cats through the sixth intercostal space. Since it is difficult to remove a desired portion of normal pleura from the cat without shredding, a segment of pleura was excised from the anterior thoracic wall with the adjacent transverse thoracic muscle. A uniform lesion, measuring 2 by 1 cm. was made and the parietal defect was outlined by silk stitches for later identification. The chest wound was closed in layers about a catheter using silk technique. The lung was re-expanded on the operating table with the aid of positive intratracheal pressure, the catheter and water-seal drainage. After maximal expansion, the catheter was removed and closure of the wound was completed.

Animals were killed at intervals from the second to the twenty-eighth postoperative days. There was no incidence of empyema and all cats did well following operation. At autopsy, the pleural wounds were removed and sections were prepared with hematoxylin and eosin and Masson's trichrom stains.

RESULTS

Gross.—During the first postoperative week, the surface of the wound was smooth and dull. There was edema of the surrounding pleura up to the fifth day. The wound was depressed, probably because muscle was removed with the pleura at the time of resection. After the first week, the lesion became progressively more glistening and at the end of two weeks, interlacing fibrous strands crossed the defect. No contraction of the wound was observed.

Adhesions were absent on gross examination. This was due perhaps to partial pneumothorax during the early postoperative period. There was also

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moderate gliding motion of the lung over the anterior chest which would prevent adhesions at the site of such a minor injury.

Microscopic.—Two days after operation the parietal wound was covered with a thin layer of fibrin that extended over the adjacent normal pleura. Beneath this was a vacuolated layer of fibrin containing a small number of leucocytes (Fig. 1). Most of these were mononuclear although a significant number of polymorphonuclear cells were present. These cells infiltrated the subjacent fat, facial and muscle planes which were edematous. The edge of the wound was well delineated by the discontinuity of the subpleural collagen layer.

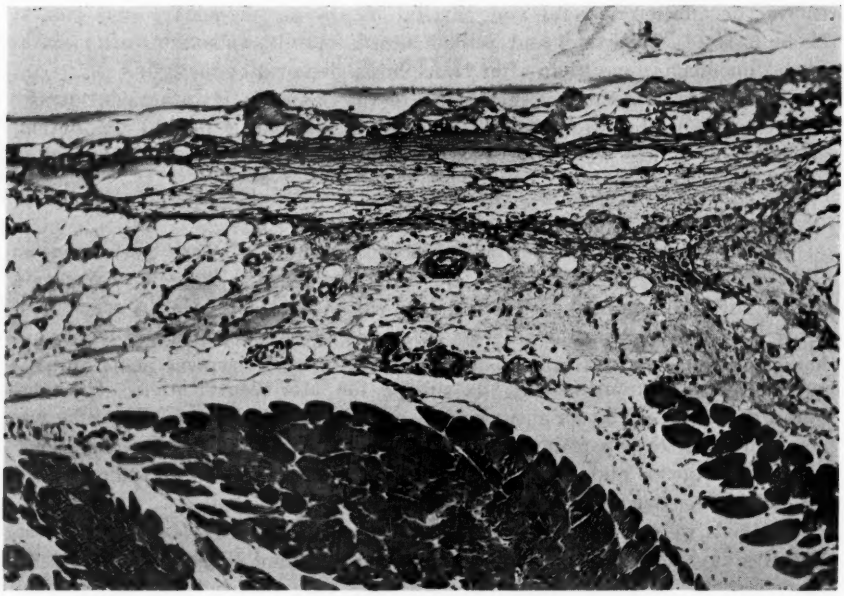

Fig. 1.—Pleural wound two days after operation. Note irregular fibrin layer containing few inflammatory cells. ×124.

Leucocytic infiltration of the wound and adjacent tissues gradually increased up to the fifth day. Mononuclear cells predominated. There was progressive thickening of the overlying fibrin layer during this period. On the fifth day the fibrin over the wound was laminated. Inflammatory cells were still present in the deeper structures, but the amount of tissue edema was diminished. There were many fibroblasts in the deeper layers of the surface exudate. They bordered the interstices of the laminated fibrin and were occasionally on the wound surface. They were particularly numerous near the edges of cut muscle. Many fibroblasts were undergoing mitosis (Fig. 2).

Fibroplasia subsequently was progressive so that by the ninth day, the wound was covered by smooth, cellular, fibrous tissue (Fig. 3). Fibrin was absent, but there were tiny capillaries in the deeper layers. A single layer of

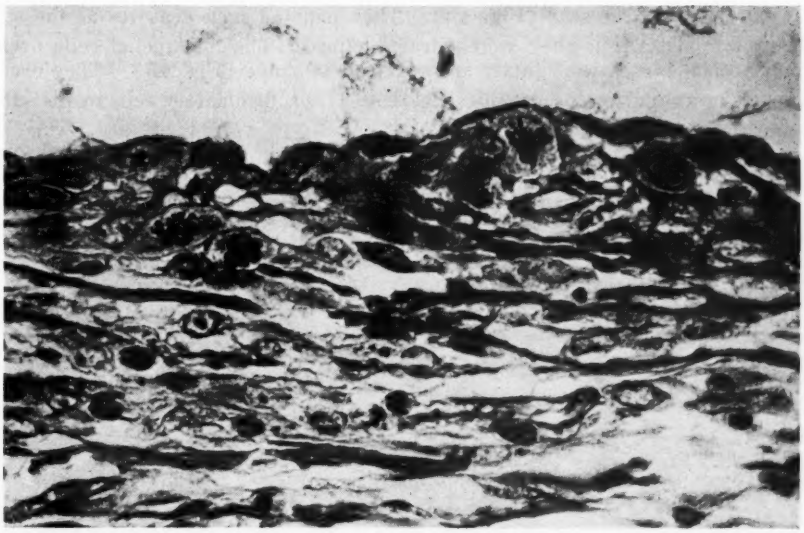

Fig. 2.—Pleural wound five days postoperatively. Fibroblasts have invaded the fibrin. Many mitotic figures are present superficially but not on the surface. ×997.

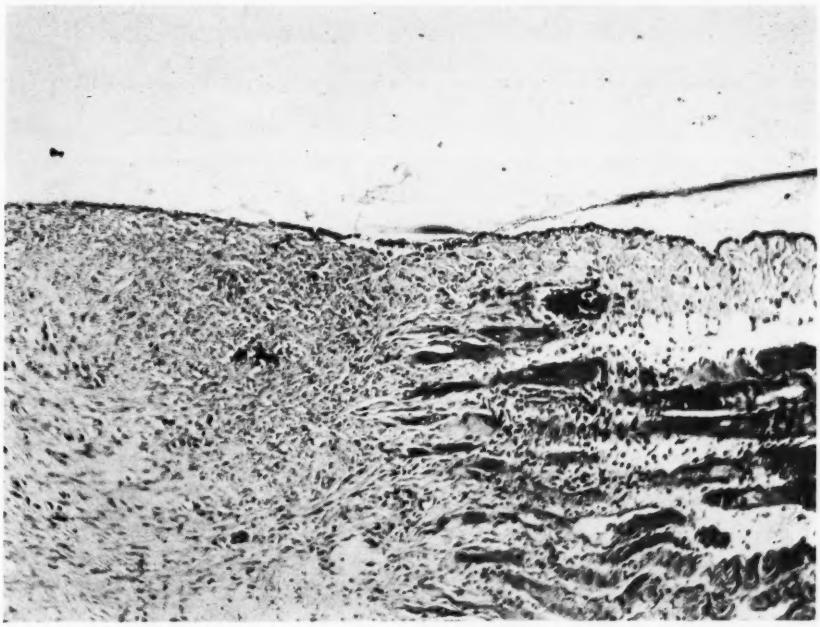

Fig. 3.—Pleural wound on the ninth day. In the right half of the picture is normal pleura. The cut end muscle is in the center and fibroblasts have filled in the defect to the left. Mesothelial cells extend for only a short distance over the scar. ×139.

flat cells covered the scar (Fig. 4*A*). They had the same features as the adjacent fibroblasts, but they were darker stained. The mesothelial cells overlying normal pleura were intact and cuboidal in shape (Fig. 4*B*). They overlapped the wound for a short distance (Fig. 3). Inflammatory cells in the subjacent tissue were rare.

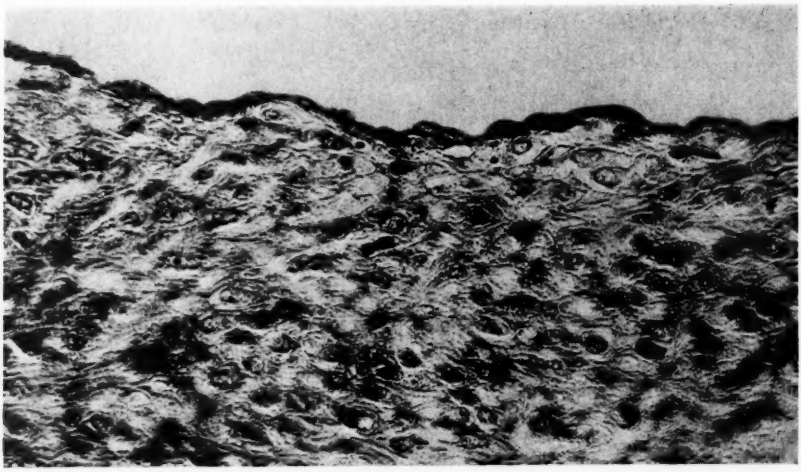

Fig. 4*A*.—Higher magnification of ninth-day wound. The surface cells have the characteristics of fibroblasts, and they are different in morphology from the adjacent mesothelial cells seen in Figs. 3 and 4*B*. ×532.

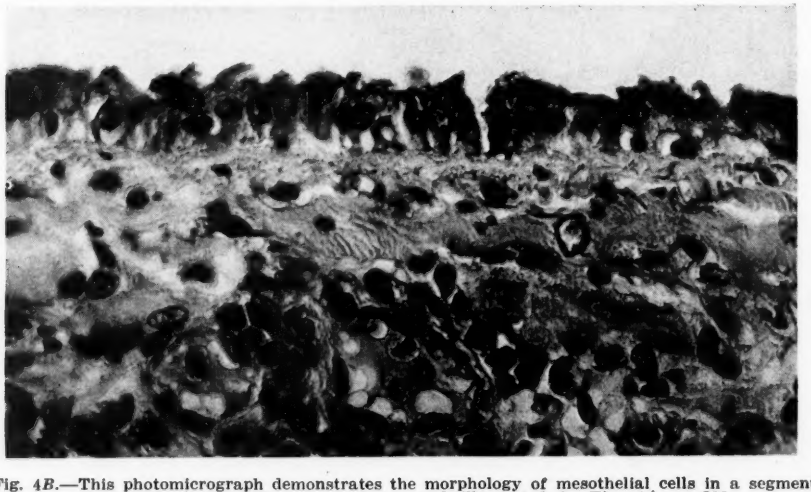

Fig. 4*B*.—This photomicrograph demonstrates the morphology of mesothelial cells in a segment of normal pleura adjacent to the wound illustrated in Fig. 4*A*. ×789.

Sections taken on the eleventh and fourteenth days showed little change. The darker staining surface cells were not always present, but they could be found usually in crypts and indentations. With maturation of the scar, it appeared that these cells were lost more easily during the routine preparation of sections. Mitotic figures were numerous, and by the end of two weeks, there was considerable collagen near the surface.

At four weeks, the scar was mature but cellular (Fig. 5). There was moderate hyalinization and capillaries invaded the entire layer.

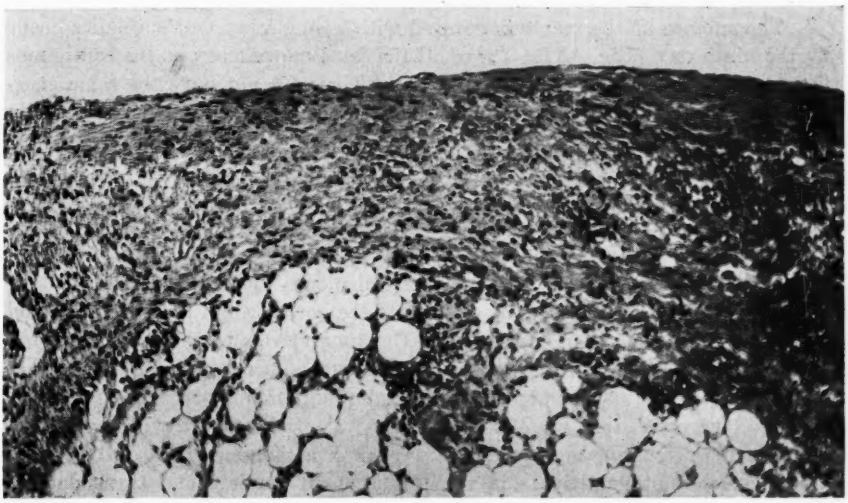

Fig. 5.—Pleural wound twenty-eight days postoperatively. Note the increase of collagen. (See text.) ×139.

DISCUSSION

In the absence of infection and adhesions, the wound resulting from a limited pleural resection heals with a smooth surface. Fibrin overlays the defect soon after injury (Fig. 1) and during the first five days, the fibrin layer gradually thickens. Leucocytic infiltration of the wounded area and adjacent tissues is minimal at first, but inflammatory cells become progressively more numerous during the first five days. Most of these cells are mononuclear. Polymorphonuclear cells are seen on the second and third postoperative days in small numbers, but they are rare after the fifth day.

Fibroplasia was not active until the fifth day. It was most evident in the deeper layers and especially near the cut ends of muscle. More rarely were they seen in the superficial layers. Fibroblastic mitoses were numerous up to the second week. They were often seen superficially but never on the surface (Fig. 2). By the ninth day, sufficient fibroplasia had occurred so that the surface of the scar was level with the adjacent pleura (Fig. 3). At this interval, reparative tissue had completely filled the defect that was originally depressed.

Contraction of the wound did not occur due to rigidity of the surrounding structures. In this experiment the deposition of collagen was first evident in the superficial layers of the wound at two weeks and this process continued throughout the wound up to the fourth week (Fig. 5).

At the end of one month, the average thickness of the scar was less than one millimeter. Sarot re-explored a patient one month after a pneumonectomy and total pleurectomy for tuberculosis.[5] He found the pleural cavity lined with a smooth layer of fibrous tissue that was one-sixteenth of an inch thick. Histologic findings of the removed specimen did not exemplify uncomplicated healing, since there was probably tuberculous involvement of the tissue.

The surface of the scar was covered with a single layer of specialized cells by the ninth day (Fig. 4*A*). They had the same morphology as the contiguous fibroblasts, but they were more basophilic. They did not have the same characteristics as the mesothelial cells over the adjacent pleura. This was especially noticeable when the latter cells were cuboidal (Fig. 4*B*). Mesothelial cells extended across the border of the wound for only a short distance (Fig. 3). As the scar matured, the surface cells shed more easily. They were often removed during routine preparation of the sections. The cells, however, could be seen in crypts of the surface of the wound twenty-eight days old.

In conclusion, denudation of the parietal pleura yields a thin, smooth scar if no infection supervenes. It is difficult to see how it could limit mobility and expansion of the adjacent structures. The reparative elements in these small wounds originated in the underlying fixed tissue. There was no evidence that the contiguous normal pleura contributed to the healing process. It may be assumed, therefore, that more extensive removal of the pleura will heal in the same manner. From the histologic appearance, a thoracic wall lined by such a scar should not participate in the formation of exudate and transudate as readily as normal pleura. The ability to absorb gas or fluid should also be diminished.

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ALVEOLAR-CELL TUMORS OF THE LUNG*

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ALVEOLAR-CELL tumors of the lung are recognized as one of the rare pulmonary neoplasms. In recent years scattered cases have been reported under two common headings: "alveolar-cell carcinoma" and "pulmonary adenomatosis." Malassez[1] reported the first case of nodular alveolar-cell carcinoma in 1876, and in 1903, Musser[2] described the first case of diffuse alveolar-cell carcinoma. In 1907, Helly[3] reported the first case of pulmonary adenomatosis. The lessions in all these cases were morphologically the same. From this time to April, 1949, 51 acceptable cases of pulmonary alveolar-cell tumors were reported under the two headings given above. However, the etiology of these neoplasms still remains a topic for heated debate among the histopathologists. Until definite proof can be established that these pulmonary tumors are derived from either ectodermal or mesenchymal tissue, the term "alveolar-cell tumor," first introduced by Neubuerger,[4] is still the most acceptable name.

Pulmonary alveolar-cell tumor in man is only one of many pathologic conditions in which cells line the alveolar spaces. In 1943, Geever, Neubuerger, and Davis[5] outlined fifteen general conditions in man and animals in which the alveoli were lined with epithelial-like cells. The disease, jagziekte, of sheep is mentioned by many authors as being similar to alveolar-cell tumors in man. However, jagziekte is seen mainly in Africa, Europe, Montana, and Iceland. From Dungal's[6] report, in 1946, it appears almost certain that this is an infectious disease which is not transferable to man. It is true that the microscopic picture of jagziekte is similar to that of alveolar-cell tumor in man, but this is also true of many types of pneumonia.

MATERIAL AND METHODS

The first case of surgically excised alveolar-cell tumor of the lung (Case 1) was encountered at the Mayo Clinic in 1943. Since then there have been 6 other cases in which operation was performed. The clinical history, laboratory reports, and pathologic aspects were studied in these 7 cases. Special stains were used on the resected pulmonary tissue, including hematoxylin and eosin, Gömöri reticulum, mucicarmine, Sudan IV, and van Gieson stains. The cells of each tumor were graded on a basis of 1 to 4 to designate their relative state of anaplasticity, grade 1 representing the least change and grade 4 the greatest change.

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REPORT OF CASES

CASE 1.—A 54-year-old woman first registered at the Mayo Clinic on Feb. 3, 1943, because of a severe nonproductive cough which had been present for one year. During this period she lost twelve pounds (5.4 kilograms). She gave a history of tuberculosis in the family. The erythrocytes numbered 4,730,000 and the leucocytes 6,200, the hemoglobin measured 13.1 Gm., the sedimentation rate was 32, roentgenograms of the thorax revealed a pathologic process at the base of the left lower lobe, and multiple tests for tuberculosis gave negative results. Bronchoscopy also gave negative results. No cytologic examination was made.

Fig. 1 (Case 1).—Alveolar-cell tumor of the nodular type involving the lower left lobe. Multiple mucoid-appearing nodules are present.

Left lower lobectomy was done on Feb. 15, 1943, by one of us (Clagett). No evidence of metastasis was found in the left side of the thorax at operation. The entire lobe was replaced by a pinkish mass, which on cut surface was composed of nodules that tended to become confluent (Fig. 1). The pleura was not involved. The cut surface of the tumor was glistening. Histologically the picture was that of a typical alveolar-cell tumor with the cells showing only a moderate degree of irregularity (grade 2). Numerous cells contained mucus (Fig. 2). The stain for fat showed fat in the interalveolar septa but none in the tumor cells. There were numerous lipophages in the neoplastic as well as in the nonneoplastic alveoli. The reticulum stain revealed that the alveolar septa were intact in the region of the tumor. The patient died on the fifth postoperative day of myocardial infarction. Necropsy disclosed no tumor in the lobes of the right or left lung. There was no metastasis elsewhere.

CASE 2.—A 55-year-old white woman gave a history of nonproductive cough and dyspnea of two years' duration. Nine months prior to admission, after an attack of influenza, she noticed that she was having a great amount of fatigue. One month before admission she began to notice progressive anorexia and nocturnal dyspnea. Shortly thereafter, she began having nausea, vomiting, chills, and fever. Two days prior to admission her cough became productive of blood and pus. This was followed by pain in the left upper part of the thorax. She gave no history of loss of weight. Her past history was noncontributory except for pneumonia several years prior to admission. On physical examination the border of the liver was palpable and the blood pressure was 178 systolic and 94 diastolic expressed in millimeters of mercury. Otherwise the examination gave negative results. The erythrocytes numbered 4,830,000, the leucocyte count was 4,800, a serologic reaction for syphilis was negative, the hemoglobin content was 14.2 Gm. per 100 c.c. of blood, the sedimentation rate was 46 mm. in one hour (Westergren), urinalysis gave negative results, and the acid-fast stain did not disclose any tubercle bacilli but cytologic examination of the sputum revealed carcinoma cells that appeared to be of the alveolar-cell type. Roentgenograms gave evidence of pneumonitis of the lingular portion of the left upper lobe. Bronchoscopy gave negative results.

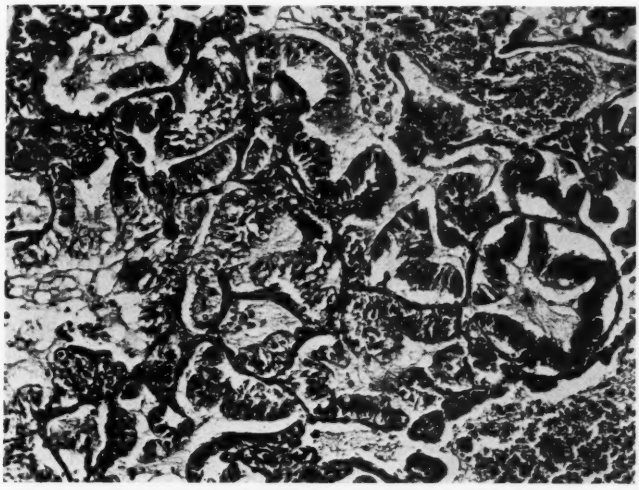

Fig. 2.—Same case as in Fig. 1. Numerous cells contain mucus. Multiple lipophages in the alveoli (hematoxylin and eosin, ×125).

Left upper lobectomy was performed. At operation no evidence of metastasis was found. Grossly the lingular portion of the upper lobe was involved with pinkish-white tumor which appeared nodular on cut surface. There was no pleural involvement. Microscopic examination revealed typical alveolar-cell tumor with moderate irregularity of the nucleoli (grade 2). The mucicarmine stain gave mildly positive results. The reticulum stain showed intact alveolar septa. The stain for fat disclosed a large amount of fat in the alveolar septa but none in the cells.

The patient was living and well six months after operation, with complete relief of cough and dyspnea.

CASE 3.—A 47-year-old white woman was admitted with the history that a severe attack of bronchitis had occurred four years previously. Two years before admission, a severe productive cough developed; this was accompanied by one episode of hemoptysis. Penicillin

therapy was instituted with relief of symptoms. Seven months before admission she again had a cough that was productive of watery sputum and was accompanied by substernal discomfort after coughing. All studies for tuberculosis gave negative results. On physical examination the left lower part of the thorax was dull to percussion, and a few râles were present. She gave a history of having had pneumonia three times and pleurisy three times. The erythrocytes numbered 4,610,000, the leucocyte count was 5,700, a serologic reaction for syphilis was negative, urinalysis gave negative results, the sedimentation rate was 18, the hemoglobin content was 10.8 Gm., and the roentgenogram showed an area of pneumonitis in the left lower pulmonary field. Bronchoscopic examination gave negative results. Cytologic examination was reported as giving negative results at that time, but later the cells seen in the sputum were classified as carcinoma cells. Left lower lobectomy was performed. At the time of operation no evidence of metastasis was found. On gross examination the lower four-fifths of the lobe was solidified and airless and was replaced by a pinkish-white tumor.

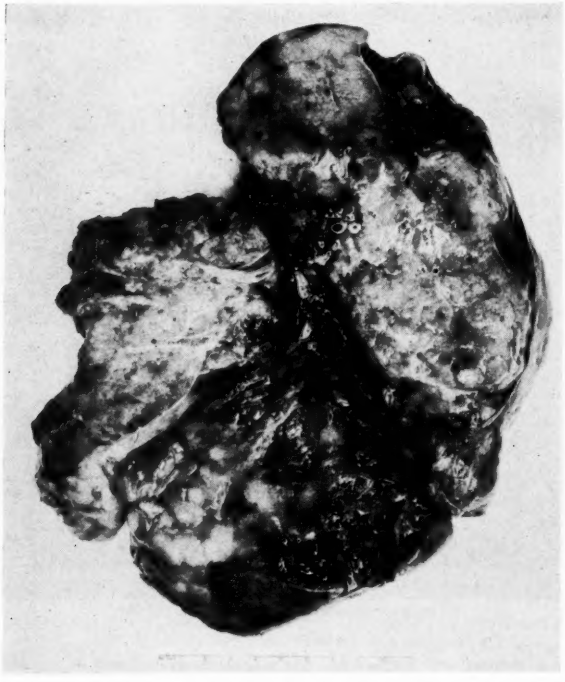

Fig. 3 (Case 4).—Alveolar-cell tumor of both diffuse and nodular type involving the entire right lung. Note the diffuse tumor in the middle lobe and the nodular appearance of the upper and lower lobes.

The remainder of the lobe had scattered nodules averaging 0.5 cm. in diameter. No pleural involvement was found. On microscopic examination the pulmonary alveoli were lined by cells characteristic of alveolar-cell tumor (grade 2). The mucicarmine stain gave negative results. The reticulum stain showed the alveolar septa intact. No fat was seen when the tissue was stained with Sudan IV.

The patient was living and well one year after operation.

CASE 4.—A 53-year-old white man came to the clinic with the chief complaint of intermittent dry cough of five years' duration which had turned productive of thick yellow mucus

two weeks prior to admission. One year prior to admission during one of his coughing attacks, he had been given penicillin with relief of symptoms. His past history revealed exertional dyspnea of a mild nature for ten years, chronic alcoholism for five years, pneumonia at 14 years of age, and malaria seventeen years prior to the admission. The erythrocytes numbered 4,830,000 and the leucocytes 6,200 per cubic millimeter of blood, 84 per cent of the leucocytes were polymorphonuclear cells, a serologic reaction for syphilis was positive, urinalysis gave negative results, and the roentgenogram showed a dense hemispherical shadow on the right with its flat surface against the posterior axillary portions of the sixth to the tenth ribs. The lateral roentgenologic view revealed emphysema of the middle lobe and contraction of the right lower lobe. Bronchoscopic examination gave negative results. Cytologic examination of three specimens of sputum also gave negative results.

Fig. 4.—Same case as in Fig. 3. Note the marked amount of mucus in the alveolar spaces and the large voluminous cells on intact septa (hematoxylin and eosin, ×200).

Right pneumonectomy was performed. At the time of operation no evidence of metastasis was found. Grossly, the right middle lobe was airless, voluminous, and completely replaced with a pinkish tumor which on cut surface was mucoid. The right upper and lower lobes were not as diffusely involved as was the middle lobe but they contained many nodules that measured 5 mm. to 1 cm. in diameter (Fig. 3). The mucoid appearance was similar to that seen in the middle lobe. Microscopic examination revealed that the pulmonary alveoli in the tumor portions were lined by columnar cells having voluminous cytoplasm and small nucleoli (grade 1 malignancy). The most marked feature was the production of mucus which was evident not only in the tumor cells but also in the adjacent lumina of the uninvolved pulmonary alveoli (Fig. 4). The alveolar septa were not thickened and were easily demonstrated by the reticulum stain. There were many lipophages in the involved as well as in the uninvolved alveoli. All parts of the tumor revealed similar structure.

Six months after operation there was roentgenographic evidence of recurrence in the left lung.

CASE 5.—A 30-year-old white woman gave a history of productive cough without hemoptysis for fifteen months. After these symptoms had continued for five months she was sent to a tuberculosis sanatorium because of suggestive roentgenographic evidence obtained by her physician. One month after admission to the sanatorium she began having afternoon fever,

night sweats, limited hemoptysis, exertional dyspnea, and pain in the left lower part of the thorax following deep inspiration. After five months in the sanatorium she was dismissed because all investigation for tuberculosis had given negative results. However, she continued having productive cough, afternoon rise of temperature, fatigue, and dyspnea until her admission to the clinic. Prior to admission she had lost nineteen pounds (8.6 kilograms). Physical examination gave essentially negative results on admission except for a few râles in the bases of both lungs. The past history was noncontributory except for a severe bronchitis ten years prior to admission and one attack of pleurisy. The erythrocytes numbered 4,110,000 and the leucocytes 7,300, the value for hemoglobin was 12.4 Gm., a serologic reaction for syphilis was negative, the sedimentation rate was 37, urinalysis gave negative results, and the roentgenogram showed dense infiltration of the left retrocardiac region posteriorly with parenchymal infiltration of the right midpulmonary field. There was also parenchymal infiltration in the upper part of the left lung. On bronchoscopy no lesion could be visualized but biopsy of tissue taken from one of the roentgenographically positive regions proved the lesion to be alveolar-cell tumor. Cytologic studies of sputum and bronchial secretions obtained the same day were all positive for carcinoma cells that were consistent with the diagnosis of alveolar-cell tumor. Acid-fast stains of the sputum were negative for tubercle bacilli.

Because of the nature of the lesion it was decided to do a segmental resection of the involved lobes on both sides. Left lower lobectomy was done first. Two months later, right upper lobectomy with segmental resection of the right lower lobe was performed. On gross examination two-thirds of the left lower lobe was replaced by a pinkish-white, airless mass. The remaining lobe appeared to be normal grossly at the time of operation. The pleura was uninvolved. The right upper lobe was also partially replaced with pinkish tumor which tended to show nodularity, with the nodules ranging from 0.5 to 1 cm. in diameter. There was some puckering of the pleura but otherwise it was uninvolved. Microscopically the tumors in the different lobes presented similar histologic appearances. The cells had pinkish cytoplasm and fairly regular nuclei (grade 2). The tumor was thrown into papillary infoldings. The reticulum stain showed that the septa were intact. A moderate amount of mucus could be demonstrated by the mucicarmine stain.

The patient died on the sixth postoperative day of right-sided heart failure.

CASE 6.—A 34-year-old white woman came to the clinic with the chief complaint of recurrent pain in the back for a period of two months. For four months she had noticed a swelling in the right cervical region. Biopsy of a node at that time disclosed hyperplastic lymphadenitis. Her one respiratory complaint was cough for three years. Her past history was noncontributory except for right-sided pleurisy seventeen years prior to admission. The erythrocytes numbered 4,490,000 and the leucocytes 9,500, the results of urinalysis were negative, the leucocyte differential count was normal, the blood phosphorus measured 3.9 mg. per 100 c.c., the sedimentation rate was 81, and the roentgenograms of the thorax revealed a lesion in the left lung posterior to the hilum with some appearance of pleural involvement. Bronchoscopy gave negative results. Cytologic examinations of the sputum and bronchial secretions were not done.

Left lower lobectomy was done. No evidence of metastasis at the time of operation was noted. On gross examination the entire lower lobe was voluminous, solid and airless. The cut surface was pinkish and had the consistency of liver. There was some nodularity. On the anterior surface there was puckering of the pleura but otherwise the pleura was uninvolved. Histologically the alveolar septa were lined by cells having pinkish cytoplasm which in places was clear. The cells were thrown in papillary infolds. The reticulum stain revealed intact alveolar septa. The stain for fat showed fat in the interalveolar septa but none in the tumor cells. The tumor cells had fairly large nuclei and varied considerably in size (grade 3). The mucicarmine stain gave positive results in some parts of the section.

Four years after lobectomy cervical lymphadenopathy developed. Biopsy revealed Hodgkin's disease. The patient died two years later. Necropsy was not done.

CASE 7.—A 62-year-old white woman gave a history of nonproductive cough of seven months' duration. Her cough was aggravated by walking, but there was no history of dyspnea

or orthopnea. She gave no history of loss of weight. Her past history was noncontributory except for scarlet fever and influenza. The erythrocytes numbered 4,930,000 and the leucocytes 11,100, the value for hemoglobin was 13.2 Gm., urinalysis gave negative results, and the roentgenogram revealed a pathologic process in the base of the left lung behind the heart. A second roentgenogram six weeks later showed increase in the lesion previously noted. Bronchoscopy gave negative results but cytologic examination of the bronchial washings disclosed malignant cells.

Left lower lobectomy was performed. At the time of operation no evidence of metastasis was found. On gross examination the entire lower lobe was involved with a pinkish-white tumor in which there was a 5 cm. cavity filled with bloody fluid (Fig. 5). Along the base of the lobe the tumor was nodular. There was no involvement of the pleura. Microscopically the pulmonary alveoli were lined with columnar cells which demonstrated pink cytoplasm and were forming papillary infoldings (Fig. 6). There was a fairly marked irregularity of the nucleoli (grade 3). The mucicarmine stain gave slightly positive results. The reticulum stain demonstrated that the alveolar septa were intact between the tumor cells.

Two years after operation the patient was living but was complaining of pain in the back.

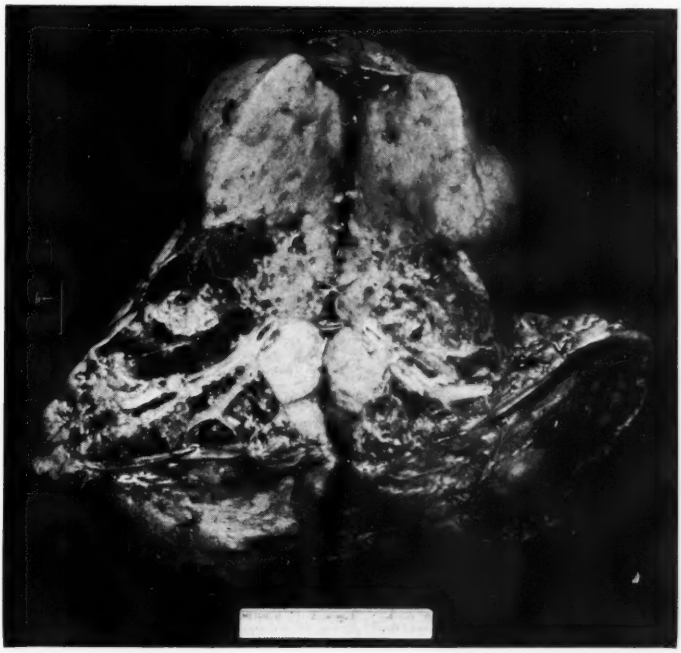

Fig. 5 (Case 7).—Alveolar-cell tumor of both nodular and diffuse type with cavitation in the left lower lobe. The entire lobe is involved. A 5 cm. cavity and multiple nodules in the base are present.

COMMENT OF CASES REPORTED HEREIN

Gross Pathologic Features.—Of the 7 patients just reported on, 4 had involvement of the left lower lobe; 1, the entire right lung; 1, the left upper lobe; and 1, multiple segments of both lungs. Multicentricity of the lesions was evi-

dent in all cases even though in 4 cases the lesions were generally diffuse. Around these diffuse lesions were many small nodules, indicating multiple focal points of growth. The possibility of tumor spread by direct extension was considered but ruled out because of lack of microscopic evidence. On cut section these tumors all had a whitish to pink appearance and the consistency of liver. In 2 cases there were cavities that contained a blood-tinged watery fluid. It was particularly noticeable that none of the tumors had invaded the bronchi or pleura. No evidence of metastasis was noted at operation or on gross inspection of the specimens.

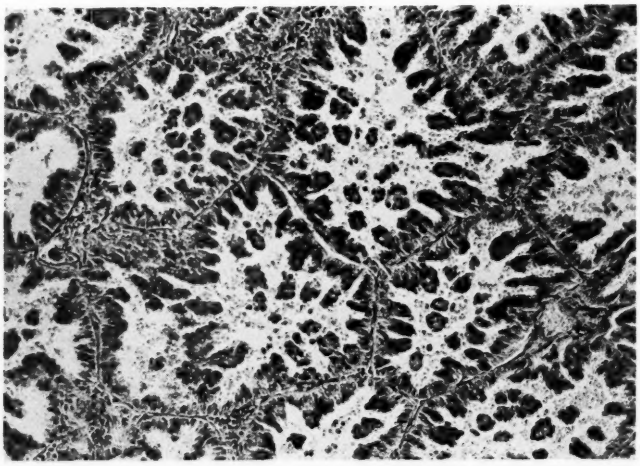

Fig. 6.—Same case as in Fig. 5. Note preservation of the alveolar septa and the presence of papillary infolding (hematoxylin and eosin, ×100).

Microscopic Aspects.—All the lesions were characterized by the presence of pinkish cytoplasm in the alveolar cells. The cells varied from tall-appearing columnar to large nucleated cuboidal cells. All the tumors showed papillary infoldings of the alveolar lining cells as well as cells in multiple clumps in the aveolar lumina. Few mitotic figures were seen. With the mucicarmine stain mucus was demonstrated in all but 1 case. In 2 of the cases mucus could be seen in the cytoplasm of the cells. The reticulum stain showed that all the septa were intact. The stain for fat demonstrated fat in the alveolar septa in 5 cases and none in 2 cases. In no instance was fat noted in the cytoplasm of the tumor cells.

Clinical Manifestations.—The chief complaint generally was cough which was usually nonproductive at first but later became productive. One patient had had no respiratory complaints. Two patients had had mild attacks of hemoptysis. Three patients had noticed dyspnea and fatigue. Two patients complained of loss of weight of twelve and nineteen pounds, respectively, in less than one year. Other symptoms were pain in the back, anorexia, pain in the thorax,

orthopnea, and night sweats. On physical examination few signs of clinical importance were found except decreased breath sounds over the affected pulmonary areas. Previous diseases recorded were 2 cases of influenza, 2 cases of bronchitis, 2 cases of pleurisy, and 1 case of chronic alcoholism. Data on other previous disease were noncontributory. Roentgenographic examination demonstrated the lesions in all cases, but the lesions could not be differentiated from other inflammatory or neoplastic disease. The erythrocytic count did not drop below 4,110,000. The highest leucocyte count recorded was 11,100 and the lowest 4,800. The value for hemoglobin varied from 10.8 to 14.8 gm. The sedimentation rates varied from 14 to 81. All bronchoscopic examinations gave virtually negative results; however, in 1 case a bronchoscopic biopsy specimen taken blindly from a region which showed a pathologic process roentgenographically presented evidence of alveolar-cell tumor. A bronchogram taken in 1 case demonstrated nothing but a lack of filling of the terminal bronchi in the region of the tumor.

Roentgenologic Examination.—There were no characteristic roentgenologic findings as have previously been reported by Good, McDonald, Clagett and Griffith.[7]

Cytologic Examination.—Cytologic examination disclosed the presence of carcinoma cells in 4 of the 7 cases. In 2 cases cytologic examination was not carried out, and in 1 case the results of such examination of the sputum were negative. Microscopically the cells in the smears of sputum and bronchial secretion have the same appearance as those seen lining the alveoli. They are usually seen in clumps or rows. Their cytoplasm is very pale pink and the nuclei vary in shape and staining reaction consistent with alveolar-cell tumor. From the microscopic appearance of the tumor one would expect to find alveolar cells in all cases of this disease because of the free clumps of tumor cells seen in the alveolar lumina in the 7 cases reported herein. From a diagnostic standpoint cytologic examination offers the only positive laboratory aid in the diagnosis of alveolar-cell tumor.

Subsequent Course.—Of the 7 patients operated on 3 were living and well two years after operation; of the 3 reported living and well 1 patient (Case 2) returned one year after operation with a recurrence which was diagnosed by cytologic examination of the sputum. One patient died two years after operation from what was apparently Hodgkin's disease. One patient died on the sixth postoperative day of right-sided heart failure following bilateral segmental resection in two stages two months apart. One patient died of a coronary infarct on the sixth postoperative day, and 1 returned six months after operation with roentgenographic evidence of involvement of the opposite lung.

STATISTICAL STUDY OF DATA ON ALL REPORTED CASES

The statistics which follow are based on the 51 cases reported in the literature [1-4,8-35] and the 7 cases reported herein. In many of the case reports the authors listed little more than the pathologic findings. Consequently data on many of the clinical features were few.

Forty-one per cent of the patients were male and 59 per cent were female. Sixty-one per cent of the patients were in the fifth decade of life, 11 per cent were in the third and sixth decades, and 5 per cent were in the second and seventh decades. The ages ranged from 17 to 89 years. The 7 cases reported by us comprised 25 per cent of the cases of surgically excised tumors of the lungs seen at the Mayo Clinic before April 1, 1949. In 69 per cent of the cases the disease affected both lungs while in the remaining cases it was confined to one or two lobes. Fifty per cent of the lesions were of the nodular type, 36 per cent were diffuse, and 14 per cent were both nodular and diffuse. In 48 per cent of the cases there was metastasis; of these, in 30 per cent the metastasis affected the liver, in 77 per cent the regional lymph nodes, in 18 per cent the brain, and in many cases skeletal and generalized metastasis occurred. In 22 per cent of the entire group there was cavity formation. Microscopically, in 48 per cent of the cases the lesions were composed of columnar cells and in 15 per cent they were made up of cuboidal cells; in the remaining cases the lesions were of mixed columnar and cuboidal types. In 74 per cent of the cases there were papillary projections, and in 60 per cent there were mitotic figures.

The chief clinical symptoms were dyspnea in 67 per cent of the cases, productive cough in 43 per cent, nonproductive cough in 35 per cent, hemoptysis in 27 per cent, and thoracic pain in 18 per cent. The average duration of symptoms was two months, with a range of one to forty-eight months.

The average erythrocyte count was 4,320,000, the average leucocyte count was 9,682, the average value for hemoglobin was 12.8 Gm., and sedimentation rates varied from 6 to 81 mm. Urinalysis gave negative results in all cases. One author reported positive results with examination of the sputum for malignant cells. In 4 of our 7 cases malignant cells were found in the sputum, in 1 case malignant cells were not found, and in 2 cases cytologic examination was not done.

Reports of previous illnesses were noncontributory.

SUMMARY AND CONCLUSIONS

Seven cases of alveolar-cell tumor of the lung in which surgical resection was done have been reported. These cases have been added to the 51 cases reported in the literature before April, 1949, and a statistical survey of the combined groups has been made.

The histogenesis of alveolar-cell tumors points toward an epithelial origin.

Although alveolar-cell tumors have been reported as nodular and diffuse, both forms appear to be the same. From the gross appearance of the lesions in our 7 cases it seems likely that the nodular form is primary and that the nodules later coalesce to form a diffuse tumor.

The symptomatology offers little of diagnostic significance, the chief symptoms being dyspnea and cough. The incidence of alveolar-cell carcinoma is less than 3 per cent of all surgically excised pulmonary neoplasms. The tumor is seen slightly more often in women than men. Most of the patients were in the fifth decade of life.

Cytologic examination of sputum and bronchial washings offers the only positive preoperative diagnostic aid. Roentgenograms of alveolar-cell tumors may simulate both inflammatory and neoplastic disease of the lung.

Surgical resection of the affected pulmonary region offers the only treatment of value at present. If patients are allowed to go without removal of the alveolar-cell tumor, they will die of asphyxia, metastasis, or obstructive pneumonitis. Although these tumors often show multicentricity, operation should not be denied them if it is performed only for palliation.

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OBSTRUCTING INTRABRONCHIAL HODGKIN'S DISEASE

Case Report

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HEREIN is reported a case of an unusual endobronchial tumor which was shown to be Hodgkin's disease by bronchoscopic biopsy specimen. A left supraclavicular lymph node biopsy supported this diagnosis. To our knowledge the literature has recorded only one other case in which an ante-mortem diagnosis of endobronchial Hodgkin's disease has been made in this manner. Hammond,[1] in 1941, reported a 15-year-old boy with a partial tracheal obstruction and a mediastinal mass. Bronchoscopy was performed twice for the diagnosis and to relieve the obstruction. A right tracheal-wall pedunculated tumor just above the carina and acting in a ball-valve manner on the right main-stem bronchus was found. The second bronchoscopic biopsy revealed Hodgkin's disease. X-ray therapy was instituted.

Autopsied cases of intrabronchial Hodgkin's disease have been described. Murchison,[2] in 1870, reported a 6-year-old girl in whom the smaller bronchial walls were replaced with "adventitial tissue" typical of Hodgkin's tumor. In 1885, Ribbert[3] recorded narrowing of the bronchial tree by intramural Hodgkin's disease. There may be partial[4, 5, 6] or complete[7-10] bronchial occlusion from extra,[11, 12, 13] or intramural, tumor causing partial or total pulmonary atelectasis.[10, 12, 14] Tracheal involvement[1, 5, 15] and tracheoesophageal fistula[16] have been reported.

The incidence of Hodgkin's disease is given as 0.24 per cent by Wallhauser[17] (15,783 routine autopsies) and as 0.33 per cent by Jackson[18] (18,668 routine autopsies). Intrathoracic involvement (autopsy and chest roentgenogram) varies from 40 per cent to 80 per cent.[4, 10, 14, 19, 20] In 212 cases, Goldman[21] found 30 of 89 (33 per cent) "early cases" and 94 of 124 (76 per cent) "late cases" had intrathoracic Hodgkin's disease. Intrabronchial involvement was found in 2 of 18 autopsies by Moolten[10]; 2 of 16 autopsies by Krueger and Meyer[14]; and 2 of 10 autopsies by Fraenkel and Much[22] in cases of known Hodgkin's disease (over-all average of 13.6 per cent). Moolten believed that bronchial involvement must be thought of as among the most typical features of pulmonary Hodgkin's disease.

Pathologically Hodgkin's disease is now generally classified in the lymphoma group.[23, 24] The pulmonary lesions may be primary (autochthonous), originating from the lymph nodules within the lung parenchyma or submucosa of the bronchi or secondary, by direct extension or metastatic spread of the tumor cells.[19, 25]

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Pulmonary Hodgkin's disease has been macroscopically classified in essentially similar manners by various authors.[4, 16, 18, 20] Hartfall's[26] classification is listed:

1. Root infiltration from a mediastinal glandular mass.
2. Massive intrapulmonary Hodgkin's disease.
3. Diffuse fibrous infiltration (which proves to be Hodgkin's disease microscopically).
4. Discrete or nodular disseminated Hodgkin's disease.

The lesion then progresses:

1. By direct extension into the lung.
2. By extension along the bronchi.
3. Lymphatic spread via:
   a. peribronchial
   b. perivascular
   c. subpleural
   d. interstitial
4. By vascular involvement, for example, by entry into the bronchial or pulmonary veins or arteries.
5. By a combination of the preceding.

Others have divided the disease according to the microscopic appearance and have made prognostic correlations.[13, 18]

Willis[25] lists the microscopic spread of malignant tumors in general in the following ways: (1) Direct extension into and infiltration of the tissue spaces along anatomic cleavage planes by the tumor cells with progression in size of the lesion. This is always the initial and most fundamental mode of spread. (2) Invasion of, and progression along, the lymphatic vessels. (3) Invasion of the veins and capillaries with thrombosis and tumor emboli. Willis believed that Hodgkin's disease may spread in the same manner. "Hilar lesions may surround and invade the main bronchi, and so may be indistinguishable grossly from bronchogenic carcinoma." The term "pan-bronchitis" has been used for the total replacement of the bronchial wall with tumor cells and the inflamed appearance of the mucosa.[27, 28]

The following case correlates the clinical features of an obstructing bronchial tumor with the diagnosis of Hodgkin's disease. Such correlation has been reported previously only in autopsied cases, except for the one reported by Hammond.

CASE REPORT

R. G. H., a 24-year-old white man, entered the Veterans Hospital, Portland, Ore., on July 18, 1949, for treatment of a bronchiogenic carcinoma.

On May 7, 1949, the patient was hospitalized elsewhere with a right lobar pneumonia (chills, temperature, 105° F.). One month prior to admission, he had had cough, fatigue, and irritability. After six days of hospitalization and Crysticillin therapy, he returned home feeling well. On May 23, 1949, the patient was readmitted because of sudden right pleuritic pain and constant low-grade fever. A chest roentgenogram revealed clouding in the right lower lung field. Despite Crysticillin and aureomycin therapy, the patient maintained a low-grade fever with elevations to 102° to 103° F. Two thoracenteses were performed, the first yielding no fluid, and the second, 12 c.c. of sterile sanguineous purulent fluid. Repeated chest roentgenograms revealed no change.

On June 23, 1949, the patient was transferred to a second hospital where he was reported to have right lower lobe atelectasis. He was placed on streptomycin therapy. On July 2, 1949, bronchoscopy was reported to reveal a large granulomatous plug obstructing the right lower segments. This plug on removal and on pathologic examination was reported as squamous-cell bronchiogenic carcinoma. Meanwhile, the patient coughed up large amounts

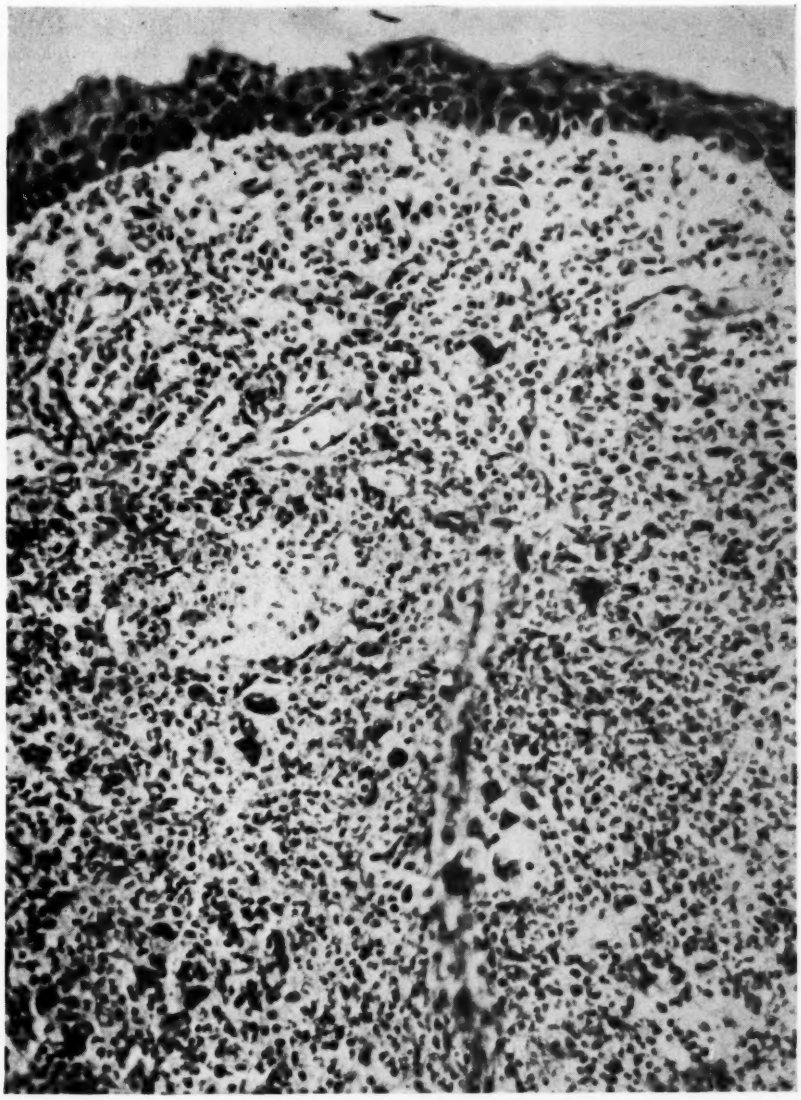

Fig. 1.—Photomicrograph of bronchial biopsy specimen revealing Hodgkin's disease involving bronchial mucosa with squamous metaplasia of the epithelium. ×150.

of mucopurulent sputum, following which auscultation revealed breath sounds over the right lower lobe for the first time in over one month. The patient was then transferred to the Portland Veterans Hospital.

Interim history revealed a ten-pound weight loss, easy fatigability, and intermittent cough with minimal expectoration of blood-streaked phlegm. Systems review was otherwise noncontributory.

Physical examination revealed a young, well-nourished, well-developed white man in no acute pain or distress. Temperature was 98.2° F., pulse 94, respiration, 20, and blood pressure, 136/92. There was a small, firm, freely movable, left supraclavicular lymph node palpable. Chest examination showed lag in motion and decreased expansion on the right. There was dullness, decreased breath sounds, and increased vocal and tactile fremitus at the right base. No râles were heard. Physical examination otherwise was within normal limits.

Summary of Hospital Progress.—On admission, July 19, 1949, the laboratory studies revealed an essentially normal urinalysis, white blood cell count, and differential white blood cell count. The hemoglobin was 12.5 grams per cent and the red blood cell count, 4.5 million. The Kahn was negative. The sedimentation rate was 35 mm. per hour.

Roentgenograms of the chest revealed a lobulated mass in the right hilar region blending with the radiopacity in the right base. The trachea and the mediastinal structures were shifted to the right; the right diaphragm was not seen. Impression was of collapse of the right lower and middle lobes with effusion.

During the next week, repeated episodes of hemoptysis (blood-streaking to one-half cup of bright red blood) occurred. Cytologic studies of the sputums revealed inflammatory cells, except for one which showed large single cells with acidophilic nucleoli which may have been tumor cells.

A left supraclavicular lymph node biopsy was performed on July 27, 1949. The microscopic diagnosis was Hodgkin's disease.

On July 28, 1949, bronchoscopy under topical cocaine anesthesia revealed a whitish, nodular tumor mass arising from the medial, anterior, and lateral wall of the proximal end of the right main bronchus. The level of origin was less than 0.5 cm. from the carina which was noted to be thickened, shortened fore and aft, and broadened with the appearance suggesting extraluminal bifurcation masses. It was impossible to enter the right main bronchus, but several large biopsies of the mass were obtained. The gross appearance was not altogether typical of carcinoma but certainly suggested it. Microscopically these biopsies showed chronic inflammation.

X-ray therapy to the mediastinal mass and the lymph node biopsy site, as recommended by the Tumor Board, was begun on Aug. 3, 1949. The status of the bronchial lesion was as yet undetermined. The bronchial plug specimen obtained by bronchoscopy at the other hospital on July 2, 1949, revealed no tumor cells on microscopic review.

Bronchoscopy and biopsy were again performed for diagnosis on Aug. 11, 1949. There was no change in the endoscopic appearance of the tumor. This biopsy of the right mainstem bronchus and tumor revealed microscopically a layer of squamous epithelium which would represent a metaplasia of the bronchial mucosa. Immediately beneath this layer of epithelium there was a mass of cells; within this mass were numerous, various sized, large lobulated cells of the Reed-Sternberg type, as well as granulocytes and other degenerating cells. Diagnosis was Hodgkin's disease involving bronchial mucosa with squamous metaplasia of the epithelium (Figs. 1 and 2).

Three weeks after x-ray therapy was begun, a roentgenogram of the chest revealed a decrease in the hilar tumefaction on the right to about 60 per cent of the original size, with more clearing of the collapse at the right base. Seven days later (Aug. 31, 1949) a repeat roentgenogram of the chest showed an almost complete x-ray expansion of the right lower lobe. There was still a suggestion of a mass at the right hilar region.

The x-ray therapy was completed on Sept. 2, 1949. In thirty-one days the patient had received 1,800 r to the right anterior chest, 1,800 r to the right posterior chest (crossfiring the

right hilar mass), and 1,500 r over the left cervical port (lymph node biopsy area) using a Thoraeus filter. The patient's blood picture was followed by a complete blood cell count every two to four days while under treatment. The white blood cell count varied from 5,000 to 9,000 with an essentially normal differential white blood cell count, the eosinophil count never exceeding 4 per cent. The hemoglobin rose from 12.5 to 14.5 gram per cent.

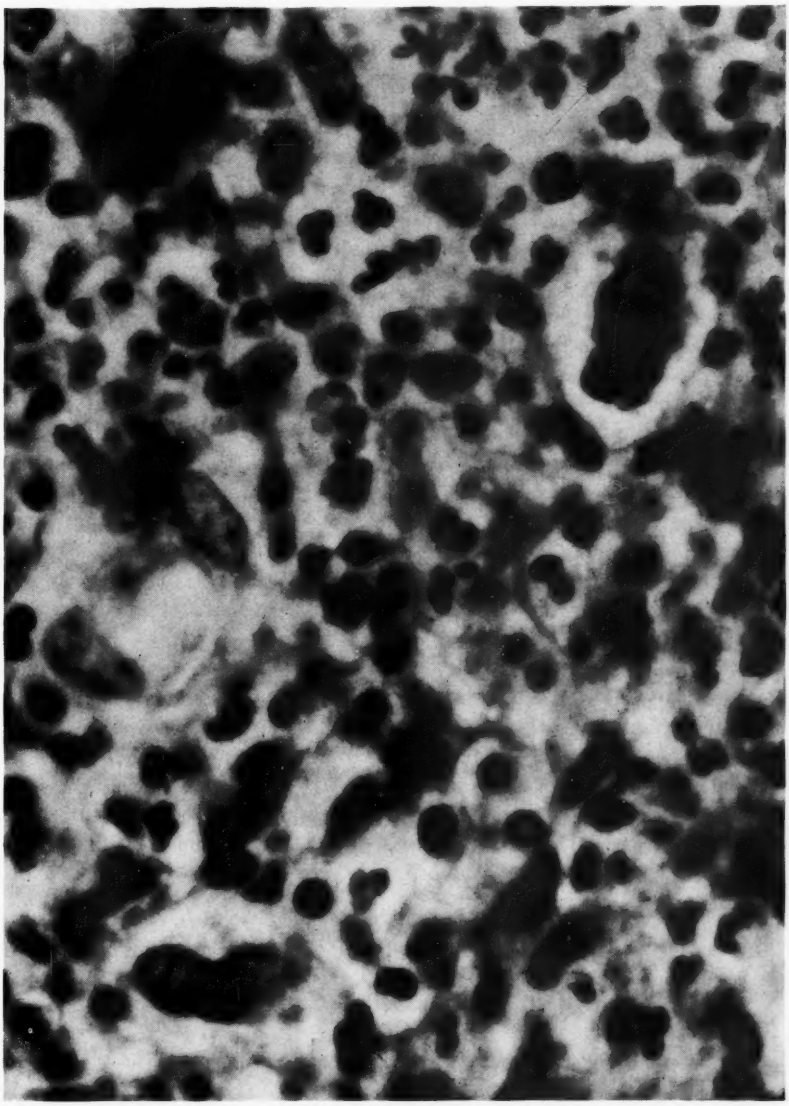

Fig. 2.—Photomicrograph of bronchial biopsy specimen revealing characteristic cellular elements of Hodgkin's disease. ×900.

The patient received no other treatment except general supportive therapy and one course of crystallin penicillin of 100,000 units every three hours from July 20 to Aug. 3, 1949. The temperature graph revealed an average periodic evening rise to 99.8° F. during this same period, remaining normal thereafter.

Clinically the patient had gained weight, had become cheerful and optimistic. There was complete pulmonary expansion with good breath sounds over the right chest. Patient was therefore discharged.

On Jan. 9, 1950, approximately four months after completion of the x-ray therapy, the patient returned for re-examination by the Tumor Board. He had no complaints, had maintained his weight, and was working. Clinical examination was within normal limits. A chest roentgenogram was essentially the same as on Aug. 31, 1949. Bronchoscopy at this time revealed normal bronchial trees bilaterally; all orifices were identified on the right and there did not appear to be any mucosal irregularity. The patient was discharged for further Tumor Board follow-up study.

DISCUSSION

Several points are of interest in the preceding case.

1. As with any type of obstructing bronchial lesion, the initial phase was of a partial collapse, stasis of bronchial secretions, and finally pneumonitis, this last causing symptoms that forced the patient to seek medical aid. The pneumonitis cleared on antibiotic therapy only to reappear because the basic lesion remained unchanged. Finally, as the obstruction became complete, antibiotic therapy had no appreciable effect.

2. In the other case reported in the literature analogous to the preceding one, despite a seemingly adequate biopsy (as also in our case) on the first bronchoscopy, a microscopic diagnosis could be made only of inflammation. A second bronchoscopy and biopsy were needed for the true diagnosis.

3. This case exemplifies the paucity of physical signs pathognomonic of classical Hodgkin's disease. Also the dramatic response of this disease to adequate x-ray therapy.

4. Routine bronchoscopy in all cases of Hodgkin's disease, even without clinical evidence of bronchial obstruction, might prove of value diagnostically, therapeutically, and statistically.

5. The fact that primary pulmonary Hodgkin's disease, though certainly not common, can simulate acute inflammatory disease, pulmonary abscess, primary tuberculosis, and bronchiogenic and metastatic carcinoma[18] cautions the diagnostician to use all facilities in making an accurate etiological diagnosis of any pulmonary lesion.

SUMMARY

A case of obstructing intrabronchial Hodgkin's disease diagnosed by bronchoscopic biopsy specimen is reported. A review of the literature is included.

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A TECHNIQUE FOR THE SURGICAL TREATMENT OF CONGENITAL EVENTRATION OF THE DIAPHRAGM IN INFANCY

Report of a Case

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THE surgical management of congenital eventration of the diaphragm in infancy has rarely been the subject of published reports. Only two cases that have undergone successful operation were discovered in the literature, both of these appeared in the past two years.

This case is reported because it differs from the previous two in that it occurred on the left side, the infant was younger, and there was a different type of operative technique employed.

Bisgard[1] described the first surgical correction of this condition in an infant aged 6 weeks. His method consisted of a transthoracic operation for a right-sided eventration with plication of the diaphragm using three superimposed rows of interrupted mattress sutures of silk. The pleat, thus formed, was turned downward between the diaphragm and the liver. The diaphragm was of normal appearance consisting of muscle and an excellent result was reported twenty-two months following the operation.

State[2] has recently described a transabdominal technique by means of which he corrected a right-sided eventration in a male infant 6 weeks of age. Exposure was made through a subcostal incision. The diaphragm was found to be of normal muscular development but high in position reaching to the second interspace anteriorly. The anterior portion of the diaphragm was brought down and sutured to the anterior costal margin. The posterior part of the diaphragm was then united to the right crus and renal fascia. To prevent pressure on the newly formed diaphragm, only the skin of the abdominal wall was closed. The incisional hernia, thus created, was repaired a year later.

CASE REPORT

M. S., a 9-day-old white female infant was referred* to the Children's Hospital on May 17, 1949. Delivery had been difficult and prolonged. The child was cyanotic at birth. Voluntary respirations were established finally, after a trial of several hours with artificial measures. Following this the baby again became cyanotic whenever food was offered or upon crying. Oxygen was administered most of the time. There was a progressive weight loss from 7 pounds 4 ounces at birth, to 6 pounds, 2 ounces.

Admission examination showed a fairly well-developed baby who breathed with obvious difficulty. No difference was noted between the expansion of the two sides of the thorax. The percussion note was hyperresonant on the left although good breath sounds could be heard on that side. The heart tones were best heard at the right border of the sternum.

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1. 2. 3.

Fig. 1.—Roentgenogram taken nine days after birth.
Fig. 2.—Roentgenogram taken immediately following operation.
Fig. 3.—Roentgenogram taken ten days postoperatively.

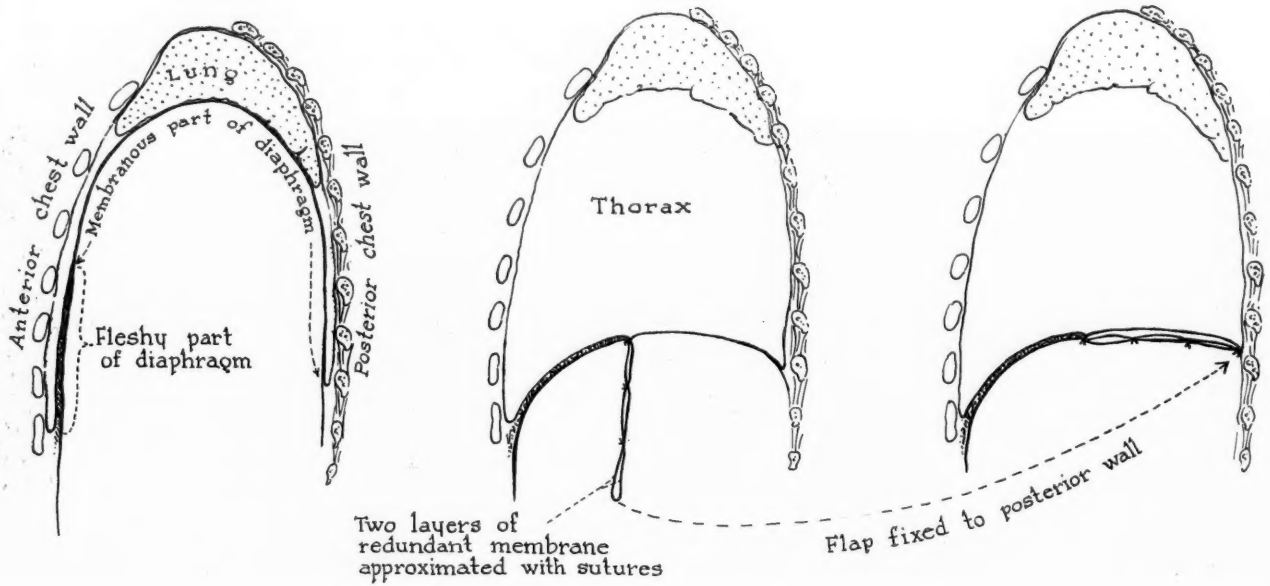

Fig. 4.—Diagrammatic representation showing repair of eventration.

A roentgenogram of the chest showed the left diaphragm to extend above the third rib posteriorly. Beneath the thin line representing the diaphragm could be seen the gas shadows of the stomach and colon. The heart shadow was seen to be almost entirely in the right chest. A diagnosis of eventration of the diaphragm was made and operation was performed on the day of admission.

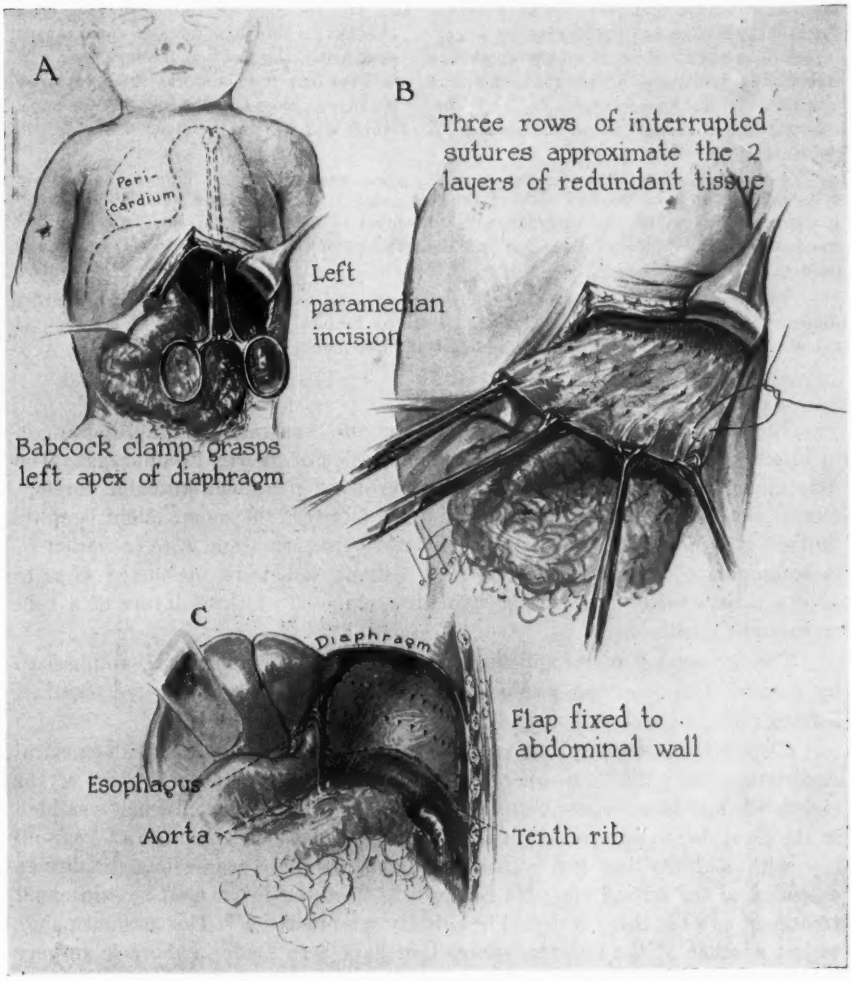

Fig. 5.—Appearance of the reconstruction of the diaphragm.

Under intratracheal cyclopropane and ether anesthesia, the abdomen was explored (W. L. B.) through a left upper rectus incision. The stomach, spleen, and splenic flexure of the colon were in the thoracic cage. As they were drawn down one could see the glistening thin membrane which was the diaphragm lining the chest cavity; it was like looking down a large empty gun barrel. Babcock forceps were used to grasp the apex of this tunnel. The diaphragm was brought down and everted out through the abdominal

incision. It was apparent that only its anterior half was composed of muscle. The posterior portion was a thin translucent membrane resembling pleura. Sutures placed in this portion caused needle punctures as they do in pleura. The redundant diaphragm was plicated with three rows of interrupted sutures of fine silk. The final row united the edge of the muscular anterior half to the membranous posterior half so that a normally positioned diaphragm resulted. The broad fold consisting of the two layers of membrane which resulted from the plication was then turned back and its edge sutured to the left crus, the renal fascia, and to the intercostal muscles. This gave a thickness of three membranous layers to the posterior half of the diaphragm. Apparently the weak under-developed portion of the diaphragm which was membranous and rose into the chest was the area corresponding to the foramen of Bochdalek. The abdomen was closed with figure-of-eight steel wire sutures in rectus muscle and sheath. A catheter was left in the stomach for decompression.

A roentgenogram taken in the operating room showed the left lung to be entirely collapsed due to air that had entered the left chest through openings made in the membranous diaphragm by the suture needle. Removal of 110 c.c. of air and a repeat film showed the left lung to be expanded and the left leaf of the diaphragm to be in a normal position.

The postoperative course was entirely without incident. The preoperative respiratory difficulty disappeared at once. The child left the hospital in ten days. Fluoroscopy of the diaphragm on discharge showed the left leaf to be moving normally.

COMMENT

The preceding two cases operated upon for eventration of the diaphragm in infancy found in the literature were eventration of the right diaphragm. The diaphragm in each instance was described as being of normal muscular development. Both authors have commented on the fact that the repair might be quite difficult if a diaphragm consisting of a translucent membrane were encountered. A technique is described in which such a diaphragm is reconstructed so as to give a satisfactorily functioning structure composed of three layers of a thin translucent membrane.

The importance of recognizing eventration of the diaphragm is emphasized by Eggers[3] who described a case where the margins had been sutured together, leaving a sac in the chest in a 4-week-old child who later succumbed.

Clopton[4] presented a child twenty months old before the American Surgical Association that had been operated upon for empyema thoracis, part of the eighth rib had been resected, and a tube placed in the stomach which was high in the chest due to eventration of the diaphragm. He also presented a 6-year-old boy with malnutrition and attacks of abdominal pain whose left diaphragm extended to the second rib. He concluded, "Nothing much need be said about treatment as what there is should be entirely symptomatic." This account points to but another of the many advances that have been made in thoracic surgery in the past twenty-five years.

CONCLUSIONS

1. A technique for successful transabdominal repair of eventration of the diaphragm is described.

2. The transabdominal approach is favored in this condition as affording a stronger repair and more accurate anchorage of the diaphragm.

ADDENDUM

The child was re-x-rayed a year after operation. The diaphragm was one interspace higher.

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RESPIRATORY AND CIRCULATORY STUDIES IN PATIENTS AFTER BILATERAL LOBECTOMY

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MULTILOBAR resections for the treatment of bilateral bronchiectasis have been performed with increasing frequency in recent years. Eloesser[7] was the first to report a successful case of bilateral lobectomy. He resected the right and left lower lobes in a young woman in 1931 and 1932. A similar case was reported by Lewis[11] in 1936. In the same year Churchill[4] reported the removal of the right middle and left lower lobes in a patient with situs inversus. Overholt,[12] in 1937, described a four-stage resection of the right middle and lower and left lower lobes.

Graham[9] was the first to resect all but the two upper lobes. In a boy 14 years of age he removed the right middle and lower lobes in 1938, and the lingula and left lower lobe in 1940. This patient, alive and well today, is included in the present study.

Since these early reports many surgeons have had an opportunity to do bilateral lobar resections (Ross,[14] Bradshaw and Chodoff,[3] Churchill,[5] Bisgard and Swenson,[2] Kergin,[10] and Adams[1]).

No physiologic data are available concerning patients in whom several lobes have been removed. The present study was therefore undertaken. Of the 14 patients who have undergone bilateral lobectomy for bronchiectasis in Barnes Hospital since 1938, only one patient has died. This individual, a 34-year-old woman on whom the lingula and left lower lobe and the right middle and lower lobes were removed in two stages, died two days after her second operation. The cause of death was pulmonary edema and bronchopneumonia. One other patient has not been followed, although she was discharged from the hospital in good condition after having the right middle and lower lobes and left lower lobe removed in 1946 and 1947, respectively. A clinical follow-up was obtained on the remaining 12 patients and physiologic studies were performed on 10 of these.

MATERIAL

Of the 14 patients operated upon, 10 were female and 4 were male with ages ranging from 6 to 34 years at the time of their first operation. The average duration of symptoms preceding surgical intervention was fourteen years. The onset of symptoms began with pneumonia in 6 cases, whooping cough in 3, and smallpox in 1. In the remaining the onset was insidious. Frequent respiratory

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TABLE I

NAME AND	AGE*	OPERATIONS	RESULTS†

TABLE 1

NAME AND SEX	AGE*			LOCATION OF DISEASE	OPERATIONS				RESULTS†	
					FIRST STAGE		SECOND STAGE		FIRST STAGE	SECOND STAGE
	A	B	C		LOBES REMOVED	COMPLICATIONS	LOBES REMOVED	COMPLICATIONS		
J. L. R. (M)	14	15	26	RML, RLL Ling. LLL	RML, RLL (T)‡	Small empyema without BP fistula	Ling. LLL (T)	Sterile pericardial effusion	Fair	Excellent
S. S. W. (F)	6	7	15	RML, RLL Ling. LLL	RML, RLL (T)	Small BP fistula healed spontaneously	Ling. LLL (T)	BP fistula healed spontaneously	Poor	Fair
G. C. (M)	8	8	17	RML, RLL Ling. LLL	RML, RLL (T)	Atelectasis LUL, wound infection	Ling. LLL (IL)‡	BP fistula and empyema, measles, scarlet fever	Fair	Excellent
E. L. V. D. (F)	27	28		RLL Ling. LLL	Ling. LLL (T)	Small empyema healed spontaneously	RLL (IL)	None	Fair	Fair
B. W. (F)	23	24	27	RML, RLL Ling. LLL	Ling. LLL (IL)	None	RML, RLL (IL)	None	Fair	Excellent
E. P. (F)	24	25	-	RML, RLL Ling. LLL	RML, RLL (IL)	None	LLL (IL)	None	Fair	No follow-up
I. H. (F)	28	31	34	RML, RLL Ling. LLL	Ling. LLL (IL)	BP fistula, empyema, incomplete expansion RUL	RML, RLL (IL)	Intercostal neuralgia relieved by neurectomy	Poor	Poor
K. G. (F)	22	23	24	RLL Ling. LLL	Ling. LLL (IL)	None	RLL (IL)	RML atelectasis cleared on tracheal aspiration	Fair	Fair
H. M. (M)	16	17	20	RML, RLL Ling. LLL	Ling. LLL (IL)	None	RML, RLL (IL)	BP fistula healed spontaneously	Fair	Excellent
J. L. D. (F)	34	35	-	RML, RLL Ling. LLL	Ling. LLL (IL)	None	RML, RLL (IL)	Pulmonary edema and bronchopneumonia	Fair	Died 2nd postoperative day
H. S. (M)	21	21	23	Ant. seg. RUL RML, RLL Ling. LLL	LLL (IL)	None	Ant. seg. RUL RML, RLL	BP fistula healed spontaneously	Poor	Poor
G. K. (F)	23	23	25	RML, RLL Ling. LLL	Ling. LLL (IL)	Small empyema healed after drainage	RML, RLL (IL)	None	Fair	Excellent
L. S. H. (F)	15	16	17	RML, RLL Ling. LLL	RML, RLL (IL)	None	Partial Ling. LLL	None	Fair	Excellent
M. L. (F)	23	24	25	RML, RLL Ling. LLL	RML, RLL (IL)	Empyema RUL atelectasis	LLL (IL)	None	Fair	Fair

*Age: A, at first operation; B, at second operation; and C, at time of follow-up.
†Results: excellent, sputum less than 1 tablespoon daily; fair, sputum markedly reduced; poor, marked residual bronchiectasis.
‡T, tourniquet ligation technique; IL, individual ligation technique.

tract infections, particularly sinusitis, had been present in all patients. At least 2 gave histories of chronic ear infections. Eight had noted hemoptysis during their illnesses. In 10 cases surgery of the paranasal sinuses was required.

The extent of pulmonary surgery and other pertinent clinical data are summarized in Table I.

Ten of the 12 patients who have been followed are working or attending school regularly. Their occupations for the most part are sedentary; one patient is doing farm work. Four enjoy active recreation including basketball, baseball, and bowling. These 10 individuals carry out their daily routines in an entirely normal fashion, although they do note a degree of exertional dyspnea which exceeds that of their normal companions. The 2 remaining patients are unable to work because of severe dyspnea and expectoration.

PHYSIOLOGIC STUDIES

Methods.—Vital capacity and its subdivisions were determined on a Benedict-Roth type metabolism apparatus filled with oxygen with the patient in the supine position. At least three determinations were performed with adequate periods of rest between each. The reserve and complemental volumes were measured from the end of normal expiration; that is to say, complemental air included tidal volume.

Functional residual air (F.R.A.) volumes were determined in duplicate after the method of Darling, Cournand, and Richards[6] with some modifications. In all but one patient these volumes checked within 8 per cent. Residual air volume was obtained by subtracting reserve volume from F.R.A.; total volume by adding complemental volume to it.

Gas analyses were carried out in the Van Slyke-Neill manometric apparatus using the technique described by Peters and Van Slyke[13] with minor modifications. Duplicate determinations checked within 0.03 volumes per cent.

Maximum breathing capacity (M.B.C.) was determined by using a low resistance modified Loven respiratory valve connected to a 350 liter balanced Tissot spirometer by means of 75 cm. of 3.75 cm. corrugated tubing. The determinations were done with the patient erect. Readings were made after 15 and 30 seconds and repeated after adequate rest. The largest determinations were recorded.

The patients were put through a standard exercise of walking on a power-driven treadmill at 2.5 or 3.2 miles per hour at 5° incline as long as could be tolerated up to 7 minutes. Rate and volume of respiration during each minute of exercise were measured by collecting the expired air in a Tissot spirometer. Heart rate was simultaneously recorded. During the recovery period respiration and pulse rates were determined until they had returned to normal. The ventilation reserve (V.R.) during exercise was computed from the equation

$$\text{V.R.} = \frac{\text{M.B.C./min.—Max. Vent. during exercise/min.}}{\text{M.B.C./min.}}$$

Arterial blood samples were anaerobically collected preceding and immediately following the standard exercise. The oxygen and carbon dioxide content

and oxygen capacity of whole blood and the carbon dioxide content of anaerobically separated plasma were determined, using the Van Slyke manometric apparatus.[13]

Arterial plasma pH was determined in duplicate by the Van Slyke and associates[16] photometric application of the Hastings-Sendroy bicolor method, using the Beckman Model B spectrophotometer. The calibration curve used was obtained by determining the optical density of three phosphate buffers of known pH in phenol red. A linear relationship existed between optical density and pH.

Arterial carbon dioxide tension and whole blood buffer base (carbonate plus protein) were calculated with the help of the nomogram of Singer and Hastings.[15]

Results.—The data are tabulated in Tables II, III, and IV. The values for vital capacity and total capacity were compared with those of normal individuals of comparable body build.[8] It should be understood that the normal range of lung volumes for any one group of individuals is considerable; extremes may differ from the mean by as much as 25 per cent. All but one of the patients reported in this study had total lung volumes which fell within normal range, though invariably on the low side of the mean. The one case whose total lung volume was only 58 per cent of normal was I.H., all of whose functional values were markedly abnormal and whose clinical condition was poor. This patient's vital capacity was only 30 per cent of normal; all other cases studied had diminished vital capacities though to a lesser degree (54 to 78 per cent of the normal mean).

The residual/total volume ratio, which should not exceed 30 per cent, was significantly increased in all patients. The greatest deviation was again encountered in I.H. Three of the patients showed an alveolar nitrogen percentage, after 7 miutes of oxygen breathing, above the upper limit of normal (2.5 per cent).

The maximum breathing capacity (Table III) was abnormally low in all but three cases. Table III also shows that only 5 patients tolerated the full amount of exercise on the treadmill (3.2 m.p.h., 5° incline, 7 minutes). Patient I.H. showed extreme dyspnea after only 50 seconds of walking at 2.5 m.p.h. Inability to perform the maximal amount of standard exercise in the remainder was due to extreme fatigue of the leg muscles, rather than respiratory discomfort or dyspnea. The minimal ventilatory reserve during exercise ranged from 23 to 52 per cent with the exception of patient I.H., who had practically no reserve after 50 seconds.

Respiratory rates during exercise ranged from 30 to 52 per minute and required 1 to 15 minutes to return to the resting level. Peak pulse rates of 130 to 180 per minute were encountered. The pulse returned to resting levels 4 to 15 minutes after exercise had stopped.

Arterial blood studies are summarized in Table IV. Resting arterial oxygen saturation was at the lower border of normal or low in three instances, the lowest value being 85.58 per cent. Following exercise the saturation fell in 7

TABLE II. LUNG VOLUMES[1]

NAME	TIDAL (C.C.)	COMPLEMENTAL (C.C.)	RESERVE (C.C.)	VITAL CAPACITY[2] (C.C.)	RESIDUAL[3] (C.C.)	TOTAL[4] (C.C.)	RESIDUAL/TOTAL X100 (PER CENT)	ALVEOLAR N_2 AFTER 7 MIN. O_2 (PER CENT)
J. L. R.	588	1,765	774	2,568	1,731	4,325	40.1	2.12
S. S. W.	427	1,042	560	1,628	1,190	2,792	42.6	3.07
G. C.	482	1,965	638	2,815	2,375	4,972	47.8	2.31
E. L. V. D.	535	1,525	882	2,326	2,070	4,477	46.3	2.01
I. H.	182	650	244	894	1,569	2,448	64.1	2.51
K. G.	428	1,495	481	1,922	2,264	4,205	53.9	2.26
H. M.	428	1 710	856	3,100	3 488	6,054	57.6	6.24
G. K.	—	1,475	486	1,930	1,629	3,640	44.7	1.20
L. H.	540	1,161	864	2,050	1,563	3,538	44.2	3.30
M. L.	349	1,186	648	1.890	1,449	3,283	44.1	2.55

[1]All volumes reduced to prevailing barometric pressure, 37° C., saturated with water vapor.
[2]Vital capacities were determined separately, hence are not necessarily the exact total of complemental and reserve volumes.
[3]Residual volume equals functional residual air minus reserve.
[4]Total volume equals F.R.A. plus Complemental.

TABLE III

NAME	EXERCISE*	MAXIMUM BREATHING CAPACITY (L/MIN.)		MAXIMUM VENTILATION DURING EXERCISE (L/MIN.)	MINIMUM RESPIRATORY RESERVE DURING EXERCISE (PER CENT)	PULSE			RESPIRATION		
		15 SEC. ×2	30 SEC. ×4			RESTING MAXIMUM	DURING EXERCISE	RETURN TO NORMAL (MIN.)	RESTING	MAXIMUM DURING EXERCISE	RETURN TO NORMAL (MIN.)
J. L. R.	3.2 mph 7 min.	78.7	79.3	38.1	52	76	172	10	10	30	10
S. S. W.	2.5 mph 6 min.	53.2	52.6	35.5	33.3	108	168	8	25	52	8
G. C.	3.2 mph 7 min.	86.3	87.6	47.6	45.7	100	180	10	27	36	2
E. L. V. D.	3.2 mph 7 min.	40.6	43.2	30.5	29.4	84	168	4	14	26	6
I. H.	2.5 mph 50 sec.	19.0	17.1	18.3	3.5	116	152	4	28	36	2
K. G.	3.2 mph 6 min.	41.9	45.1	34.6	23.3	96	160	7	24	42	1
H. M.	3.2 mph 5 min.	53.3	56.5	37.4	33.8	86	180	15	22	44	15
G. K.	3.2 mph 7 min.	53.3	55.2	41.3	25.2	85	136	7	16	36	5
L. H.	3.2 mph 7 min.	73.6	72.3	46.0	37.5	88	160	10	11	52	10
M. L.	2.5 mph 3 min.	40.6	41.3	31.1	24.7	100	168	5	30	48	5

*Speed and duration of walking on treadmill at 5° incline.

	3 min.													

*Speed and duration of walking on treadmill at 5° incline.

TABLE IV. ARTERIAL BLOOD STUDIES

NAME	O_2 CONTENT (VOL. PER CENT)		O_2 CAPACITY (VOL. PER CENT)		O_2 SATURATION (PER CENT)		CO_2 CONTENT PLASMA (M.MOL./L)		PLASMA pH		CO_2 TENSION* (MM. HG)		WHOLE BLOOD BUFFER BASE* (MEQ./L)	
	RESTING	AFTER EXERCISE	RESTING	AFTER EXERCISE	RESTING	AFTER EXERCISE	RESTING	AFTER EXERCISE	RESTING	AFTER EXERCISE	RESTING	AFTER EXERCISE	RESTING	AFTER EXERCISE
J. L. R.	18.93	19.00	19.90	20.28	95.13	93.73	26.35	20.69	7.42	7.30	40	40	45	41
S. S. W.	17.94	17.91	19.05	19.81	94.12	90.41	23.58	21.40	7.46	7.37	32	36	47	43
G. C.	18.59	19.34	19.37	20.19	95.98	95.81	25.23	21.01	7.45	7.40	35	33	48	43
E. L. V. D.	16.59	17.88	17.83	18.35	93.03	97.43	22.83	21.63	7.50	7.45	29	30	47	45
I. H.	16.20	17.41	18.93	18.59	85.58	93.75	30.00†	27.63	7.53	7.44	35	40	53.5	50
K. G.	12.73	13.78	13.59	14.56	93.70	94.80	24.57	—	7.48	—	—	—	—	—
H. M.	14.75	15.11	15.88	17.26	92.88	87.54	25.22	21.01	7.46	7.25	35	45	47	39
G. K.	16.37	17.02	16.18	17.58	100	96.80	21.38	19.43	7.48	7.44	29	28	44	42.5
L. H.	15.06	15.31	15.69	16.33	95.98	93.75	23.04	19.99	7.30	7.35	45	35	42	41
M. L.	18.34	17.58	20.37	21.18	92.78	85.34	26.35	26.84	7.53	7.48	31	35	51	51

*Calculated from nomogram.[15]
†Calculated from CO_2 content of whole blood.

cases. This is definitely an abnormal finding, although both pre- and post-exercise values might be within normal limits (93 per cent or more). Patient I. H. showed a marked increase in arterial oxygen saturation following only 50 seconds of mild exercise.

There was an insignificant change or a definite fall in plasma CO_2 following exercise in all cases. The plasma pH dropped in all but one instance.

The arterial carbon dioxide tension at rest was within normal limits. The tension rose or fell up to 10 mm. Hg during exercise. The whole blood buffer base, which was normal at rest, fell 0 to 8 meq/1 during exercise. This fall is due to the release into the blood stream of fixed acids (mainly lactic acid).

From examination of the chest films the lung volumes appeared within normal limits. In most instances the diaphragm on both sides showed descent on inspiration. The mediastinum was in the midline in all but a few instances in which there was deviation to one side. The lung parenchyma was clear in all cases but one which showed scattered fibrosis.

Electrocardiographic studies showed both standard and precordial leads to be within normal limits in all but one instance, in which the first two precordial leads revealed partial right bundle branch block. Notably, no electrocardiographic evidence of right ventricular hypertrophy was found in any case.

DISCUSSION AND CONCLUSIONS

In spite of the fact that the remaining lobes expanded to occupy a nearly normal volume, the vital capacity of these lobes did not increase correspondingly. This was evident from the large size of the residual air compartment in all cases studied. As far as the nitrogen content in the alveolar air after 7 minutes of pure oxygen breathing is a measurement of intrapulmonary mixing, the latter was normal in 7 out of 10 patients.

Although a large residual air compartment is found in most cases, our findings do not necessarily indicate that the remaining lobes of our patients were emphysematous. Such diagnosis was certainly not corroborated by the clinical data or by the x-ray appearance of the thoracic cage and of the lung fields. It is impossible to predict whether or not at a later date pathologic changes characteristic of chronic emphysema might develop in the excessively expanded lobes.

The alveolar ventilation at rest was adequate to allow normal arterial oxygen saturation in all but one case. During exercise the alveolar ventilation/alveolar blood perfusion relationship decreased to such an extent that the saturation fell in most instances. Factors which lead to a law ratio are large residual air compartment, poor intrapulmonary mixing (both of which were found in some of the patients), and impairment of diffusion of oxygen across the alveolar membrane. These disturbances can make themselves more apparent during moderate exertion where pulmonary blood flow is greatly increased and mixed venous blood contains less oxygen than under basal conditions. The contribution of impaired oxygen diffusion cannot be evaluated with the techiques used. In none of the patients was the maximum breathing capacity a limiting factor in the ventilatory demands made by exercise.

The ventilation during exertion was apparently sufficient to prevent excessive accumulation of carbon dioxide. The rise in CO_2 tension which was seen in a few instances cannot be considered as abnormal. The accumulation of lactic acid during exercise, as shown by the fall in whole blood buffer base, was not excessive for individuals who are on the whole poorly trained.

The rise in saturation in three instances (including the case with a low resting value) must be due to improvement in alveolar ventilation/perfusion relationships under the stimulus of exercise. Such a rise is not uncommonly seen in moderate degrees of emphysema. Factors leading to such improvement are increase in alveolar ventilation, more intimate alveolar mixing, and increased pulmonary capillary surface across which diffusion must take place. It can be concluded that in each of the patients studied ventilatory abnormalities were present, which in all but two instances lead to deficient blood oxygenation in the lungs, either at rest or during moderate exercise, or both. In spite of this all but two patients were able to lead useful lives and some of them performed moderately severe physical exercise.

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